MOVEMENT, MIGRATION, AND HABITAT USE BY COLORADO PIKEMINNOW (*PTYCHOCHEILUS LUCIUS*) IN A REGULATED RIVER BELOW FLAMING GORGE DAM, UTAH

DRAFT FINAL REPORT

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EXECUTIVE SUMMARY

The Green River below Flaming Gorge Dam to the Yampa River confluence has not been designated as critical habitat and was not considered a priority recovery area for Colorado pikeminnow *Ptychocheilus lucius*. Within the last 20 years, the abundance of Colorado pikeminnow has increased throughout Lodore canyon and fish have been captured during spring, summer, and autumn. The discovery of Colorado pikeminnow above the Yampa River confluence has indicated former habitat was being re-occupied by adult Colorado pikeminnow. The presence and abundance of Colorado pikeminnow has raised the question of whether these fish spawn in Lodore Canyon. The purpose of this study was to describe movement, migration, and habitat use of Colorado pikeminnow on the Green River in Lodore Canyon and Browns Park.

From 2000 to 2002, 78 Colorado pikeminnow were captured from May to October in Lodore Canyon. No fish were observed or collected in Browns Park. Ninety-five percent (n=75) of all Colorado pikeminnow were captured by angling from July through August. Size distribution of Colorado pikeminnow ranged from 380 mm to 820 mm TL (total length; =545 mm TL). Colorado pikeminnow were captured in runs, eddies, pools, and eddy fences.

Thirty-one Colorado pikeminnow were implanted with an internal radio transmitter. Radio-tagged fish did not establish permanent residency in Lodore Canyon. Colorado pikeminnow returned to Lodore Canyon seasonally from June through August, after peak flows (> 85 m^3/s) and as water temperatures increased (> 8°C). Radio-tagged fish were re-contacted within 0.3 to 1.6 km from their original point of capture. Colorado pikeminnow occupied Lodore Canyon from 1 to 132 d (=31 d).

Radio-tagged Colorado pikeminnow entered Lodore Canyon in late-June through mid-August, during the presumptive spawning period. Colorado pikeminnow congregated in specific locations (i.e., RK s 578.8, 576.0, and 559.1) during the presumptive spawning periods, but no direct evidence (i.e., larval Colorado pikeminnow or direct observation) of spawning or successful reproduction

was detected. Although congregating Colorado pikeminnow in itself does not mean fish were engaging in spawning, these Colorado pikeminnow were occupying Lodore Canyon during the presumptive spawning period.

Only five of 31 radio-tagged Colorado pikeminnow migrated upstream into the Yampa River far enough to be detected by the Yampa telemetry tower. We were unable to locate Colorado pikeminnow at spawning localities in Yampa and Gray canyons while conducting aerial surveys. Current conditions in Lodore Canyon may be inhibiting the ability of these fish to successfully reproduce there. Two mature, radio-tagged Colorado pikeminnow in Browns Parks never migrated downstream during the study period, which indicated individual Colorado pikeminnow may not spawn each year.

Colorado pikeminnow began to move out of Lodore Canyon from August through October to their overwintering areas in the Jensen-Ouray alluvial reach, and a few fish moved out of the canyon as late as early October. By mid September water temperatures descended to 15°C and by mid-October water temperatures decreased below 10°C, and all Colorado pikeminnow had emigrated out of Lodore Canyon. Declining water temperatures in Lodore Canyon in the fall likely prompted Colorado pikeminnow to emigrate to the more energetically efficient alluvial reaches. Radio-tagged fish traveled distances > 100 km to overwinter in the Jensen-Ouray alluvial reach. One to four radio-tagged Colorado pikeminnow per year emigrated upstream to overwinter in Browns Park, and two of these fish remained there year round.

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INTRODUCTION

Historically, Colorado pikeminnow *Ptychocheilus lucius* was widely distributed in the upper and lower Colorado River system, but historic habitat was reduced by about 71% (59 FR 13384) because of the construction of mainstem impoundments, water diversions, degraded water quality, and introduction of nonnative predators (Tyus 1990; Tyus and Haines 1991; Irving and Modde 2000). Wild populations of Colorado pikeminnow persist in the upper Colorado River basin. The greatest numbers (i.e., young, juveniles, and adults) occur in the Green River subbasin, which includes the Green, Yampa, and White rivers (Tyus 1984, Tyus 1990; U.S. Fish and Wildlife Service 2000;). There are two known spawning areas located in Yampa and Gray canyons (Tyus 1984; Tyus 1990: U.S. Fish and Wildlife Service 2000). Tyus and McAda (1984) indicated spawning occurred in white water canyons. Vanicek et al. (1970) and anecdotal information suggests Colorado pikeminnow may have spawned near the Flaming Gorge Dam site. Large numbers of Colorado pikeminnow were observed in mid-July concentrating downstream of the diversion tunnel during the construction of Flaming Gorge Dam (Modde 2001). The collection of a ripe male and abundance of Colorado pikeminnow at the dam site suggested these fish were either moving to a spawning site near or upstream of the dam (Vanicek et al. 1970; Modde 2001).

Following the closure of Flaming Gorge Dam in 1962, seasonal flow patterns were replaced by a relatively stable release pattern (Vanicek et al. 1970). Cold hypolimnetic water released from the reservoir converted the Green River below Flaming Gorge Dam from a turbid, warm river to a clear, cold river (Holden and Crist 1981; Wydoski and Hamill 1991). Biologists concluded that higher, colder water releases altered the native fish fauna and eliminated the reproduction of warm water fishes between the dam and Yampa River confluence, a 105 km reach (Vanicek et al. 1970; Holden and Crist 1981; Wydoski and Hamill 1991). In conjunction with closure of Flaming Gorge Dam, about 715 km of the Green River and its tributaries above the dam were chemically treated with rotenone to rid the new reservoir of rough or trash fishes in order to allow planted salmonids to become established (Holden

1991). Unfortunately, the detoxification stations below the dam site were unable to completely neutralize the rotenone. Rotenone eventually traveled downstream into Dinosaur National Monument. Dead and dying fish were reported along the shorelines by U. S. National Park Service personnel (Holden 1991). As a result, Colorado pikeminnow, humpback chub *Gila cypha*, bonytail *Gila elegans*, and razorback sucker *Xyrauchen texanus* were greatly reduced above the Yampa River confluence and replaced by nonnative salmonids (Vanicek et al. 1970; Holden and Crist 1981; Bestgen and Crist 2000).

In an effort to increase trout growth, penstocks on Flaming Gorge Dam were modified in 1978 to selectively withdraw warm water to improve the tailwater fishery (Muth et al. 2000). Releases were also re-regulated in 1992 to restore a more natural hydrograph by increasing spring flows, reducing summer flows, and stabilizing winter flows once ice formed in the Jensen area to mitigate physical impacts on nursery habitats of endangered fishes downstream of Yampa River confluence (U. S. Fish and Wildlife Service 1992; Muth et al. 2000). Colorado pikeminnow and other native fishes started to reappear in Lodore Canyon. Holden and Crist (1981) collected two Colorado pikeminnow, and Karp and Tyus (1990) collected three Colorado pikeminnow in Lodore Canyon. Bestgen and Crist (2000) collected 17 Colorado pikeminnow throughout the canyon during spring, summer, and autumn. The size (>500 mm total length, TL) and condition of these fish suggested Lodore Canyon was a productive environment for Colorado pikeminnow. The discovery of Colorado pikeminnow above the Yampa River confluence indicated former habitat was being re-occupied by adult Colorado pikeminnow.

This portion of the upper Green River is not designated as critical habitat and not considered a priority recovery area (59 FR 13884; Tyus and Saunders 2001). The presence and abundance of Colorado pikeminnow has raised the question of whether these fish spawn in Lodore Canyon. The purpose of this study was to describe movement, migration, and habitat use of Colorado pikeminnow on the Green River in Lodore Canyon and Browns Park. Specifically, the objectives of this study were to:

1. Determine what portions of the year do Colorado pikeminnow use the Green River in

Browns Park and Lodore Canyon.

2. Determine the environmental cues (e.g. temperature, discharge, etc.) that might trigger Colorado pikeminnow movement in and out of the Lodore Canyon.

3. Determine, during the base flow conditions (summer/fall) on the Green River, habitat characteristics (e.g. velocity, depth, substrate) Colorado pikeminnow use when occupying Browns Park and Lodore Canyon.

4. Determine where Colorado pikeminnow that spend some portion of the year in Lodore Canyon spawn (i.e., do fish migrate to Cleopatra s Couch on the Yampa River, or do they spawn in the study reach?).

5. Compare Colorado pikeminnow movement, migration, and habitat use patterns found in this study with those found in other studies on the Green, Yampa, Duchesne, White, and Colorado rivers to determine what role the study reach may play in the recovery of Colorado pikeminnow, and how the Colorado pikeminnow might respond to alternative operations of Flaming Gorge Dam.

METHODS

Study Area

The Green River is the largest tributary of the Colorado River originating in the Wind River Range of Wyoming. It flows southward through Utah and Colorado. Since October 1962, the flows of the Green River have been regulated by the operation of Flaming Gorge Dam. Dam operations have altered seasonal flow patterns and water temperatures, increased daily fluctuations in river stage, while reducing sediment loads (Hayse et al. 2000). The study area encompasses a 58 km reach below Flaming Gorge Dam that includes Lodore Canyon and Browns Park (Figure 1). Lodore Canyon and Browns Park were subdivided into five river reaches (Bestgen and Crist 2000). General descriptions of mesohabitats are described for each river reach (See page 6 for mesohabitat definition).

Reach 1 is between the Colorado-Utah border at river kilometer (RK) 612.9 downstream to Browns Park at RK 587.0. This reach is a wide alluvial valley that has a predominately sandy bottom. Large sand islands partition the Green River into main and secondary channels. Sand islands are more prevalent in this reach compared to Lodore Canyon. Large substrates (e.g. cobble and rubble) are found near the Beaver Creek confluence (RK 613.1) and upstream of Dinosaur National Monument boundary along a rock bluff on river left (RK 586.5). Mesohabitats in this reach are predominately long and slow moving runs; fewer pools, eddies, backwaters, and slackwaters are also present. Two tributaries present in this reach are Beaver (RK 611.6) and Vermilion (RK 590.5) creeks.

Reach 2, Browns Park (RK 586.8) to Winnies Rapid (RK 579.1), is the upstream reach of Lodore Canyon. A long run, with a sandy substrate bottom extends approximately 6.2 km downstream to Wade and Curtis Campground (RK 581.9). Below RK 581.9, riffles and combinations of mesohabitats (e.g. combination of eddy, riffle, run, and pool) are present. Substrates range from cobble, rubble, and boulder. Gradually, the mesohabitat becomes a run before reaching Winnies Rapids (RK 580.6). Depending on flow magnitude, a secondary channel is sometimes present on river right below Wade and Curtis Campground.

Reach 3, Winnies Rapid (RK 578.9) to Pot Creek (RK 571.0), has a long run with a sandy substrate bottom and a shoreline composed of cobble that extends into the main channel. The run extends downstream approximately 2.1 km before it turns into a rapid. Immediately below this rapid, near Trailer Draw (RK 578.4), mesohabitats alter from simple to more complex (i.e., more than one mesohabitat type). The diversity of mesohabitats (e.g. combination of eddy, riffle, run, and pool) are most noticeable above and below rapids. Substrates range from sand, cobble, rubble, boulder, and mixtures of each type. Riffles are present in this reach especially between RK 576.8 to 572.6. This reach contains three rapids, Disaster Falls (RK 575.6 to 574.4), near Buster Basin (RK 576.9), and

Trailer Draw (RK 578.4); three intermittent creeks, Buster Basin Creek (RK575.7), Zenobia Creek (RK 517.8), and Pot Creek (RK 571.2).

Reach 4, Pot Creek (RK 570.9) to Rippling Brook to (RK 563.0), contains three rapids, Harp Falls (RK 568.6), Triplet Falls (RK 566.7), and Hells Half Mile (RK 565.6) that are separated by run and riffle mesohabitats. Runs are both deep and shallow with sand, cobble, rubble, and boulder. Substrates in riffles often consist of cobble and rubble. Below riffles and rapids, multiple mesohabitats such as eddy, eddy fence, run-riffle transitions, run, and pools are present. Secondary channels are present above Harp Falls at RK 569.1 and above Rippling Brook at RK 563.6.

Reach 5, Rippling Brook (RK 562.9) to the Green and Yampa rivers confluence (RK 554.9), is the lower most canyon reach consisting of both deep and shallow runs, and riffles. Eddies and pools are also present, especially at RK s 561.9, 559.1, and 557.2 where water depths can be > 3 m. Rapids are located at Wild Mountain (RK 561.9), and RK 559.0. Alcove Brook, an intermittent tributary, is located just upstream of Limestone Campground at RK 560.0. Cobble bars are present along the shoreline and extend into the main channel. Other substrates present are sand, gravel, rubble, and boulder. At high flows (130.2 m^3/s) ,two secondary channels form at RK 562.1 and RK 560.5 but transform into backwaters at base flows (22.6 m^3/s).

Collections of Colorado Pikeminnow and Implantation of Radio Transmitters

Colorado pikeminnow were captured from 2000 through 2002 by angling (with Rapala lures) and electrofishing with a Smith-Root control unit and 4.8-m long Avon raft (Table 1). Fish were collected from April through October, but the most successful sampling efforts were performed in July and August. All Colorado pikeminnow were scanned for a Passive Integrated Transponder (PIT) tag, weighed (nearest 0.1 of a gram), and measured (total length, TL, nearest 1 mm); fish without a PIT-tag were tagged. Capture and release sites were identified using both a Global Positioning System (GPS) unit and Belknaps Revised Waterproof Dinosaur River Guide® (i.e., Flaming Gorge and Dinosaur National Monument). Description of mesohabitat at each capture site was classified as follows (modified from Bisson et al. 1982; Tyus et al. 1984; Valdez and Masslich 1989; Wick and Hawkins 1989; J. Hawkins, Colorado State University, pers. com 2003):

Backwater - a body of water with zero velocity, created by a drop in water level which cuts off flow through a secondary channel or a portion of the main river channel.

*Embaymen*t - an elongated pocket of low velocity water adjoining the main channel.

Eddy - a portion of the river, usually deeper than the adjacent channel, with a distinct whirlpool or counter-current.

Eddy fence -a portion of the river that is the interface or boundary between an eddy and main channel. Surface velocities often create little whirlpools and underwater currents are often of zero velocity.

Pool - a portion of the river that is deep and quiet relative to the main current with minimal velocity.

Riffle - a shallow, rapidly flowing section of the river where the water surface is broken into small waves by various particle sizes of substrate, wholly or partially submerged.

Run - a stretch of relatively deep, moderately fast flowing water with surface smooth and non-turbulent. A run has no large surface boils or upwellings, and it may be deep or shallow.

Adult Colorado pikeminnow were surgically implanted with 149-MHz radio transmitters (models MCFT-3L and MCFT-3A) manufactured by LOTEK Wireless Inc®. MCFT-3L transmitters (367 d) were inserted into fish that weighed more than 1000 g. MCFT-3A transmitters (912 d) were used for fish weighing more than 1500 g. Prior to surgery, pikeminnow were anesthetized with tricaine methanesulfonate (MS-222). Unconscious fish were placed belly up on a V-shaped operating tray, and the gills were irrigated with dilute MS-222 (Schmetterling 2001). A 2.5 cm incision was made anterior to the pelvic fins, above the ventral surface of the fish. The transmitter was then inserted through the incision and the external antenna was passed through a second small incision (3 mm) in the body wall posterior to the pelvic fins. After insertion of the transmitter, the incision was closed with three monofilament sutures (Ethicon® 3-0). After surgery, each fish was placed into fresh water to recover and was released near their capture location.

Ground and Aerial Telemetry Surveys

Ground surveys were conducted in 2001, 2002, and 2003 from May through September at two to four week intervals (Table 1). Field personnel used 4.8 m long Avon rafts through Lodore Canyon, and hard-bottom boats through Browns Park. This schedule covered the time period when most Colorado pikeminnow were moving into and out of the canyon, and coincided with their presumptive spawning period. Our goal was to locate each fish, observe it over a short daylight period, and record its movement and physical habitat use if discernible. Detected radio-tagged Colorado pikeminnow were monitored for 2-hr at 15-min intervals. A LOTEK® model SRX-400A scanning receiver and whip antenna was used to locate radio-tagged Colorado pikeminnow. Once a signal was detected, the location of radio-tagged fish was triangulated from the shore using a hand-held three-element Yagi antenna. Data recorded for each radio-tagged fish included date, time of day, water temperature, RK, and fish activity (e.g., mobile or sedentary). A fish was determined to be active if the triangulation point moved more than the potential error. Triangulation error for radio-tagged Colorado pikeminnow in this study was estimated to be potentially > 2 m because nine different individuals with varying degrees of experience were conducting the ground telemetry surveys. The LOTEK® model SRX-400A scanning receivers were effective at data-logging and detecting presence, but not very precise when used to determine specific fish locations and habitat use. Physical, mechanical, and biological factors such as water depth, conductivity, bounce off of canyon walls, etc.,(Freund and Hartman 2002), and firmware affected signal strength and signal interpretation. When tracking fish, signal strength readings displayed multiple times on the screen as the yagii antenna was directed to the fish location. Field personnel had to remember the last signal strength reading before re-directing the yagii antenna to a different location. This mechanical set back made to difficult to pinpoint exact locations, especially when fish were very mobile. Modde and Haines (2003) also used LOTEK® model SRX-400A scanning receivers but margin of error was not reported for diel observations. In this study, information collected for radio-tagged fish provided a general description of habitat use but this data should be weighed accordingly. In the future, margin of error needs to be computed to improve the precision of estimating fish locations. The effectiveness of the LOTEK® model SRX-400A scanning receivers needs to be re-evaluated when conducting ground surveys.

Microhabitat measurements were recorded at each triangulated point and included depth, velocity, and substrate. Water depth and velocity were measured from the raft using a Mound City ® surveyor s series leveling rod and Marsh-McBirney Model 2000 portable flow meter. Mean velocity was determined at 0.6 of the water depth when total depth was 1.0 m or less. For water depths > 1.0 m, measurements were taken at 0.2 and 0.8 of the water depth and then averaged. Dominant substrate was determined visually or by touch of hand or surveyor s rod, and classified using the modified Wentworth particle size scale (Bovee 1986) as: 1) silt, 2) silt and sand, 3) sand, 4) sand and gravel, 5) gravel, 6) cobble, 7) rubble, 8) boulder, 9) bedrock, and 10) wood. Mean daily discharge was obtained from the U.S. Geological Survey s Greendale gaging station (#0923500). Mean daily water temperatures were obtained from the U.S. Fish and Wildlife Service-Water Resources Division web site (*http://www.r6.fws.gov/riverdata/*).

Diel observations (24 hr) were also conducted from mid-May to September. The specific locations of radio-tagged fish were triangulated at 30-min intervals and if no movement was detectable, increased to 1-hr intervals. After the completion of each diel survey, mesohabitat, when discernable, was described and microhabitat variables were recorded for each triangulated location. In addition, a map was drawn to depict mesohabitats utilized by, and movements of, radio-tagged fish.

Fourteen aerial surveys were completed from 7 July 2000 to 22 October 2003 using a fixed-wing aircraft (Table 1). Flights were performed in the spring (pre-spawn), summer (spawn), and fall (post-spawn). Flight coverage along the Green River included Swallow Canyon, Browns Park National Wildlife Refuge, Dinosaur National Monument (i.e., Lodore Canyon, Whirlpool Canyon, Island-Rainbow parks, and Split Mountain), the alluvial reach below Split Mountain, and downstream to Desolation-Gray canyons (Figure 2). Flight coverage also included the lower 32.2 km of the Yampa River from Harding Hole (RK 32.2) to the Green River confluence, as well as the lower 6.4 km of the Duchesne River to the confluence, and the White River from Taylor Draw Dam (RK 167.3) downstream to the Green River confluence. Fish locations were estimated to the nearest 0.4 km, based on transmitter pulse rate, signal strength, and aircraft speed (Irving and Modde 2000). Information recorded for each aerial flight included flight date, transmitter frequency (i.e., 149.740 or 149.760), transmitter code, RK, and river (i.e., Green, Yampa, Duchesne, and White rivers).

Telemetry Stations

Four stationary telemetry data-logging stations were set up on the Green and Yampa rivers to record the movement of Colorado pikeminnow in and out of the canyons (Lodore and Yampa). All telemetry logging stations consisted of two, four-filament Yagi antennas, with the exception of the Echo Park tower above the Yampa-Green rivers confluence, which had a third antenna. One antenna was positioned to detect fish upstream, and the second to detect fish downstream. The third antenna mounted to the tower above the Yampa-Green rivers confluence detected fish movement in and out of Yampa Canyon. All antennas were connected to a LOTEK ® Model SRX 400 data logging receiver that continually scanned for the frequencies and the codes of radio-tagged Colorado pikeminnow. The data-logging receivers were powered by a photovoltaic panel equipped with a battery that stored electricity. Information stored in the data-loggers was frequency, code, date, time, and direction.

The Echo Park tower was set up above the confluence of the Green and Yampa Rivers (RK 555.7) on 20 July 2000 but not activated until 7 August 2000. One year later (23 July 2001), the telemetry station was relocated closer to the confluence (RK 554.9). The new location and the addition of a third antenna allowed us to record the movement of radio-tagged Colorado pikeminnow moving between the Yampa and Green rivers. The tower at Gates of Lodore (RK 582.9) was setup just downstream of the ranger station on 26 July 2001 at RK 584.2. On 30 May 2002, a third telemetry tower was set up on the Yampa River downstream of Cleopatra s Couch at RK 24.8. The tower was relocated further downstream in 2003 above Laddie Park at RK 17.7 to better conceal it from public view. The Yampa tower was operational in 2002 and 2003 from June through August. This time duration coincided with the spawning period of Colorado pikeminnow. In 2002, the data-logger receiver was interchanged between Gates of Lodore and Yampa River towers. A fourth tower was set up in Lodore Canyon on 16 October 2002 below Limestone Campground at RK 559.1 to determine range of movement of radio-tagged fish as water temperatures decreased. In 2003, the data-logger was interchanged between Limestone and Yampa towers, due to the limited number of data-loggers available for this study. Therefore, both towers were not continuously functioning year around. The data-logger in the Yampa tower recorded data from June through August. Afterward, the data-logger was placed into the Limestone Tower from October to May.

RESULTS

Discharge and Temperature

Mean daily flows below Flaming Gorge Dam from 2000 to 2003 ranged from 21.2 m^3/s to 133.6 m^3/s (Figure 3). Base flows in 2000 remained above 28.3 m^3/s except for 4 d in September. Mean daily maximum peak occurred on 24 May 2000 and was 130.5 m^3/s. Peaks flows remained above 113.3 m^3/s from 16 May to 14 June 2000. Base flows in 2001 were below 22.6 m^3/s for 34 d (4 July through 6 August) and afterward increased above 22.6 m^3/s. Two spikes occurred, one on 17 May 2001 (126.9 m^3/s) and the second on 22 May 2001 (127.1 m^3/s). Peak flows in 2002 occurred from 18 May to 2 June 2002, and reached a mean daily maximum of 112.4 m^3/s on 22 May 2002. After 3 June 2002, base flows remained below 25.5 m^3/s. Maximum peak was highest in 2003 compared to 2000, 2001, and 2002. Peak flows occurred from 19 May 2003 to 6 June 2003 and reached a maximum peak of 133.6 m^3/s on 21 May 2003. Mean daily discharges receded below > 25.4 m^3/s on 7 June and even dropped below 22.6 m^3/s on two occasions, 25 June to 21 July and 28 July to 1 August.

Mean daily water temperatures from 2000 to 2003 ranged from -0.1°C to 24.5°C (Figure 3). Water temperatures in 2002 were warmest and reached a maximum of 24.5°C on 15 July 2002. Each year (2000 2003) as flows increased (> 50 m^3/s) in May, water temperatures dropped below 12°C. After mean daily peak flow, water temperatures increased. In comparison with the Yampa River, flows and water temperatures increased during the spring runoff (Figure 4). Flows eventually declined throughout the summer but water temperatures continued to increase.

Collection of Colorado pikeminnow in Lodore Canyon and Browns Park

From 2000 to 2002, 78 Colorado pikeminnow were captured from May through October. All Colorado pikeminnow were captured and observed in Lodore Canyon (Figure 5). An additional eight fish were observed but not captured in the canyon. No fish were captured in the Browns Park area. Ninety-five percent (n=75 fish) of all Colorado pikeminnow were captured by angling from July through August (Table 2). Angling and electrofishing efforts prior to and during peak flows in the spring (i.e., April and May), yielded only two Colorado pikeminnow. Rain storms and associated turbidity from Red Creek made angling ineffective, especially in 2003. Size distribution of Colorado pikeminnow ranged from 380 mm to 820 mm TL (= 566 mm TL; Figure 6). Colorado pikeminnow were larger (= 608 mm TL) above Pot Creek (RK 571.2) and smaller (= 545 mm TL) below Pot Creek. Colorado pikeminnow were captured in runs, eddies, pools, and eddy fences.

In 2000, Browns Park was sampled in June with an electrofishing hard-bottom boat from the Swinging Bridge (RK 610.9) to the Lodore Ranger Station (RK 584.9), and no Colorado pikeminnow were captured or observed (Table 2). Angling and electrofishing were conducted in the lower two reaches in Lodore Canyon from Rippling Brook I (RK 563.6) to Yampa-Green rivers confluence (RK 554.9) in April, August, and September. Nine Colorado pikeminnow were captured in runs and eddies. In 2001 sampling was concentrated in Lodore Canyon. Angling was conducted from May through September. Sixteen Colorado pikeminnow were captured, mostly in July (n=6 fish) and August (n=7 fish). Most Colorado pikeminnow (n=7 fish) were collected in river reach 5 (Table 2). On two different angling trips, three to four Colorado pikeminnow were captured in the same location. Four fish were captured in July near a mid-channel rock at the base of Winnies Rapid at RK 578.7; and three fish in August at RK 559.1 in a large eddy below Limestone Campground.

From June through September of 2002, angling and electrofishing were conducted in Lodore Canyon and Browns Park. The Browns Park reach was sampled in July from Taylor Ranch (RK 624.0) to Lodore Ranger Station (RK 584.9); and in August from Swallow Canyon Boat Ramp (RK 616.4) to Lodore Ranger Station (RK 584.9). No Colorado pikeminnow were captured or observed on either trip. Schools of mountain whitefish *Prosopium williamsoni* (> 12 fish) were observed along the river bottom in Swallow Canyon. Lodore Canyon was sampled on five different occasions and 52 Colorado pikeminnow were collected; 3 in June, 12 in July, 32 in August, and 5 in September. One fish was recaptured twice. Colorado pikeminnow were mostly collected in reaches 3 and 5 (Table 2) and were captured in large eddies, deep runs, and below riffles. Non-native fishes collected were 5 smallmouth bass *Micropterus dolomieu*, 1 adult northern pike *Esox lucius*, and 1 juvenile northern pike. Multiple

Colorado pikeminnow were often captured in one location during each sampling trip. On three different trips (one in July and two in August), three different Colorado pikeminnow were captured each time above Buster Basin Creek at RK 576.0. On every trip, Colorado pikeminnow were collected below Limestone Campground at RK 559.1. Twenty-two fish were captured at RK 559.1; 2 fish in June, 6 fish in July, 13 fish in August (two trips), and 1 fish in September. Average total length of Colorado pikeminnow was 526 mm TL. One male Colorado pikeminnow (531 mm TL) captured in July was heavily tuberculated and expressing milt. This location had a diversity of mesohabitats that included an eddy, an eddy fence, a run, a backwater, a secondary channel, and a run-riffle transition zone, and was eventually referred to as Lake Limestone.

Capture History of PIT-Tagged Colorado Pikeminnow

PIT-tags were detected in 39 of the 75 fish captured (Appendix 1). These 39 PIT-tagged fish were initially PIT-tagged in Yampa, White, Duchesne, and Green rivers. All fish were PIT-tagged between 1992 2002. One fish was PIT-tagged in 1992 at the confluence of the Green-Colorado river (RK 0.0) and recaptured in 2002 in Lodore Canyon at RK 578.7. Thirteen of 39 Colorado pikeminnow were collected more than once in 2000, 2001, and 2002 by Utah Division Wildlife Resources, Colorado State University, or Colorado River Fish Project-Vernal Field Office during population estimate studies (Bestgen et al. 2005; Appendix 1). These 13 Colorado pikeminnow were captured or recaptured in upper Yampa River, middle and lower Green River (e.g., White River, White River confluence to the Colorado River confluence) before being collected in Lodore Canyon by Colorado River Project-Vernal Field Office (2000 2002). Size distribution ranged from 450 to 665 mm TL. Recapture data indicates PIT-tagged Colorado pikeminnow traveled a minimum distance of 27.0 km and maximum distance of 375.7 km (Appendix 1).

Radio Telemetry

Thirty one Colorado pikeminnow were implanted with internal radio transmitters from 2000 to 2002 (Table 3). Seven fish were implanted in 2000, 8 fish in 2001, and 16 fish in 2002. Four fish originated from reach two, 11 fish from reach three, 4 fish from reach four, and 12 fish from reach five. Twenty-six of 31 Colorado pikeminnow implanted with transmitters lived beyond one year after implantation. Five radio-tagged Colorado pikeminnow (# 22, 24, 28, 43[740,] 110) were presumed dead because each fish was contacted 3 to 4 times at the same location and was inactive. Fish mortality usually occurred within the first year of implantation. Thus, implanted fish had a survival rate of 84% past the first year. Nineteen of these 26 fish had active tags (according to expected battery life) by the end of the study in October 2003. Two radio-tagged fish (# 2, 13) were contacted two and four months, respectively, after their batteries should have been expired.

Information recorded from the data-logger showed Colorado pikeminnow emigrated annually (2000 2003) out of Lodore Canyon from August through November. Colorado pikeminnow occupied Lodore Canyon from 1 to 132 d (= 31 d) before emigrating to their overwintering area. Emigration was associated with decreasing water temperatures from 15°C to 8°C ($r= -0.74$, $P< 0.05$; Table 4) but not with discharge ($r= -0.10$, $P=0.48$). Colorado pikeminnow emigrated downstream > 100 km and upstream < 16 km from Lodore Canyon to their overwintering areas. Aerial observations conducted in the fall (October and November) and the winter (December and January) showed Colorado pikeminnow overwintered in the Jensen-Ouray and Browns Park alluvial reaches. The following spring and summer of each year, especially after peak flows (i.e., May), 4 fish (2001), 22 fish (2002), and 13 fish (2003) returned to Lodore Canyon from May through August. Movement into Lodore Canyon was associated with increasing water temperatures (> 8°C; $r= 0.59$, $P<0.05$). Spring and summer aerial flights indicated Colorado pikeminnow were found below, in, and above Lodore Canyon (Appendix 2 to 4). Colorado pikeminnow were often located within 0.3 to 1.6 km from their original point of capture.

Year 2000.--Seven Colorado pikeminnow were implanted with transmitters in August 2000 (Table 2). Colorado pikeminnow were captured in Lodore Canyon from Rippling Brook to Yampa River confluence. Average length and weight was 575 mm TL (465 to 701 mm TL) and 1,607 g (830 to 2,890 g). Three fish (# 24, 25, 27) departed Lodore Canyon in August, one fish (#29) in September, and two fish (# 26, 31) moved out of the canyon in October. One fish (#31) remained in the canyon from 22 August to 25 October, a total of 64 d. The exit date of one fish (# 28) could not be determined due to insufficient directional data. Winter aerial flights found 5 of 7 Colorado pikeminnow in the Jensen-Ouray alluvial reach on the Green River between Brush Creek (RK 489.9) and Ouray Bridge (RK 399.2; Figure 7; Appendix 2). Five Colorado pikeminnow (#26, 27, 28, 29, 31) had traveled downstream distances > 30 km (distance = 30 to 105 km). One fish (#25) was located in the Yampa River at RK 0.8.

Year 2001.--In 2001, two of the seven fish (# 24, 28) implanted in 2000 were confirmed dead and found in Whirlpool Canyon. The transmitter of one fish (#28) was found on a cobble bar at RK 547.2. Another fish (# 24) was located four times at RK 549.8, and never displayed any mobility. Three fish (# 26, 27, 31) moved into Lodore Canyon before and during spring peak flows from March through May (Figure 7). One fish (#31) was first detected on 17 April and occupied the canyon until 5 June, a total of 49 d. Two other fish (# 26, 27) periodically moved in Lodore Canyon before midnight (2000 to 2300 hr) and moved out in the early morning hours (0200 to 0600 hr) from March through June. Eventually all three fish (# 26, 27, 31) left Lodore Canyon in June, but returned back to Lodore Canyon from 27 June to 8 July. Aerial and ground surveys found these fish in the upper reaches of Lodore Canyon (reaches 2 and 3) and Browns Park (Figure 7; Appendix 2). One fish (# 25) remained in Browns Park from 12 July to 28 July, a total 16 d.

Eight more Colorado pikeminnow were implanted with radio transmitters from 24 May to 18 October 2001 in Lodore Canyon. The average total length was 690 mm TL (586 to 820 mm TL) and average weight was 2,534 g (1,808 to 3,034 g). One fish (# 02) was captured and implanted with an internal transmitter during spring peak flows (24 May 2001). It remained in Lodore Canyon from 24 May to 4 July, a total 41 d. Aerial survey conducted on 13 July indicated three fish (# 1, 26, 30) were located below Winnies Rapid (RK 578.7) and one fish (# 25) in Browns Park (Figure 7; Figure 8). Fish # 02 was not located during this aerial survey but it returned back to Lodore Canyon on 31 July and moved upstream into Browns Park. Ground surveys conducted from July through August showed two fish (# 42^{740}, 43^{740}) were traveling as a pair; and three fish (# 01, 22, 30) were always located within 0.3 to 1.6 km from their original point of capture (Figure 8; Appendix 2).

As water temperatures declined, nine Colorado pikeminnow (# 25, 26, 27, 30, 31, 42^{740}, 43^{740}, 44^{740}, 45^{740}) emigrated downstream of Lodore Canyon from 7 September and 22 October 2001 (Figure 7; Figure 8). Three fish (# 01, 02, 22) moved upstream into Browns Park from 1 November to 10 December 2001 (Figure 13). Winter aerial flights found three fish (# 02, 26, 45^{740}) in the Yampa River (RK s 0.5 to 0.8) and two fish above Lodore Canyon. One fish (# 22) was found near Grimes Bottom (RK 590.8) in Browns Park, and another fish (# 01) was located below the Lodore Ranger Station (RK 584.1) (Figure 13). Five fish (# 25, 27, 30, 42^{740}, 43^{740}) were located in the Jensen-Ouray reach (RK 455.3 to 485.9; Figure 10; Figure 13); they had traveled downstream distances > 80 km (distance = 80 to 122 km). One fish (# 44^{740}) was not found and the transmitter life-expectancy of two other fish (# 29, 31) had expired. Prior to 16 December, one fish (#02) in Browns Park moved downstream through Lodore Canyon, while average daily water temperatures in Lodore Canyon were < 1℃. The exact departure date from Browns Park was unknown due to equipment failure at the Gates of Lodore telemetry station.

Year 2002.--In 2002, entry and exits dates for radio-tagged Colorado pikeminnow was unknown from 16 December 2001 till 5 June 2002 because the data-logger at the Echo Park telemetry tower had exceeded its storage capacity. During the aerial flight in June, two fish (# 01, 22) were detected in Browns Parks (Figure 8). After 5 June 2002, the Echo Park telemetry station was functional and indicated Colorado pikeminnow moved into Lodore Canyon from June through August 2002. Three fish (# 25, 26, and 27) implanted in 2001 occupied Lodore Canyon from 22 to 132 d and were found between RK 556.7 to RK 572.8 (Appendix 3). Among the eight fish implanted in 2001, four fish (2,30, 44^{740}, and 42^{740}) returned in June and one fish (45^{740}) in July (Figure 8). Two fish (# 30, 42^{740}) periodically moved in and out of Lodore Canyon from 5 June through 23 June, and eventually moved into Lodore Canyon in late June and early July. Ground surveys showed Colorado pikeminnow were found throughout Lodore Canyon from RK 554.9 to RK 582.4 (Appendix 3). Only one fish (# 43^{740}) did not return to Lodore Canyon in 2002. One fish (# 01) remained in Browns Park for over a year. Two aerial flights located this fish near and above Vermillion Creek (RK 589.2; Appendix 3). One fish (# 22) was located at RK 580.9 (near Wade and Curtis) and was presumed dead.

Sixteen Colorado pikeminnow were captured and implanted with transmitters from 26 June and 26 September, 2002. Twelve fish were captured between RK 571.2 to RK 582, and 4 fish between RK 558.3 to RK 561.5 (Appendix 3). Total length averaged 630 mm TL (521 to 745 mm TL) and weight averaged 1,995 g (987 to 3,176 g). Following release, 3 fish (# 14, 113, and 114) moved out of Lodore Canyon the next day. Two fish (# 118, 44^{760}) displayed similar behaviors but returned back to Lodore Canyon within 24 hours. Thirteen Colorado pikeminnow (# 12, 13,15,16, 17, 41, 42^{760}, 43^{760}, 44^{760}, 45^{760}, 110, 117, 118) remained in Lodore Canyon from 4 to 69 d. From August through October 2002, all 13 Colorado pikeminnow, including 3 fish from 2000 (# 25, 26, 27), and 5 fish from 2001 (# 2, 30, 42^{740}, 44^{740}, 45^{740}) began emigrating out of Lodore Canyon. Water temperatures ranged from 8.0 to 21.3°C. The last fish detected moving downstream out of Lodore Canyon was on 16 October 2002. Colorado pikeminnow traveled distances up to 176 km to overwinter in the Jensen-Ouray alluvial reach (Figure 7; Figure 8; Figure 9). The last fish detected moving upstream into Browns Park was 10 October 2002. Two fish (42^{740} and 45^{740}) emigrated upstream of Lodore Canyon into Browns Park. Three fish (# 01, 42^{740} and 45^{740}) were now overwintering in Browns Park.

Year 2003.--In 2003, the Echo Park telemetry tower was not functional. Entry and exit dates were not constantly recorded from 23 June to 13 August 2003. After 14 August, data were continuously recorded by the data-logger. Aerial and ground surveys, and minimal stationary telemetry tower contacts showed 15 radio-tagged fish were in Lodore Canyon and Browns Park (Figure 8; Figure 9; Appendix 4). Among eight fish implanted in 2001, one fish (#02) was found in Lodore Canyon, and two fish (# 45^{740} and 42^{740}) were found in Browns Park (Appendix 4). One fish (# 42^{740}) remained in Browns Park until 4 January, and afterward moved downstream through Lodore Canyon. Thirty-eight hours later, it emigrated out of Lodore Canyon. Mean daily water temperatures from 3 January to 7 January were < 2.0°C. One fish (# 45^{740}) resided in Browns Park for over a year and was located at RK 592.4.

Twelve of the 16 Colorado pikeminnow implanted in 2002 (# 12, 15, 41, 16, 17, 42^{760}, 45^{760}, 43^{760}, 117, 118, and 13) returned back to Lodore Canyon after spring peak flows (Figure 9; Appendix 3). Twelve Colorado pikeminnow occupied Lodore Canyon from 11 August to 11 October (= 53 d; Table 4). One fish (# 118) stayed in Lodore Canyon for 90 d (22 June to 20 September 2003). Spring and fall aerial surveys showed four fish (# 13, 14, 44^{760}, and 110) were located below Lodore Canyon. The stationary telemetry tower at the confluence (when working) and ground contact attempts, indicated these four fish had not moved into Lodore Canyon in 2003 (Figure 9). One fish (# 110) was located multiple times at RK 547.1and presumed dead.

Thirteen fish located in Lodore Canyon in 2003 emigrated out of Lodore Canyon from 21 August to 01 October 2003 (Figure 16). Aerial flight conducted in October showed Colorado pikeminnow were in the Jensen-Ouray and Browns Park alluvial reaches (Figure 8; Figure 9; Appendix 4). Radio-tagged fish traveled downstream distances ranging from 34 to 142 km. Two fish (# 42^{760}, 117) moved upstream into Browns Park and traveled distances < 16 km.

Movement of Radio-tagged Colorado pikeminnow into Yampa Canyon

In 2002, two Colorado pikeminnow from Lodore Canyon were detected below Cleopatras Couch.

One fish (#25) entered Yampa Canyon on 24 June 2002 and 5 d (29 June 2002) later was detected by the Yampa telemetry tower. This fish remained upstream of Cleopatras Couch until 3 July 2002, and then moved downstream to Green-Yampa Rivers confluence. It made contact with tower at the confluence on 01 August 2002 and re-entered Lodore Canyon. The second fish (#42[740]) entered Yampa Canyon on 14 June 2002. It was detected 3 d later (17 June 2002) and moved upstream of Cleopatras Couch. This fish remained upstream for 3 d and then moved downstream on 20 June. It made contact with the Echo Park tower on 24 June 2002 and moved upstream into Lodore Canyon.

In 2003, the stationary telemetry tower below Cleopatras Couch was relocated downstream to RK 17.0, which is just upstream of Laddie Park. One fish (# 01) was detected multiple times from 21 April and 01 August. Two more fish moved into Yampa Canyon in June. The Yampa Tower detected one fish (#16) on 8 June, and the other fish (#02) on 16 June. All three radio-tagged Colorado pikeminnow did not move upstream but instead remained near or downstream of the telemetry station.

Daily Observations and Movement of Radio-Tagged Colorado pikeminnow

Daylight movements of radio-tagged Colorado pikeminnow were minimal with fish typically remaining in the area they were originally contacted in. Colorado pikeminnow were found in runs, pools, and eddies (in order of high to low use) with water depths ranging from 0.6 to 2.2 m (Figure 10). Water velocities ranged from 0.41 to 0.61 m/s. Radio-tagged Colorado pikeminnow tended to maintain positions over sand and rubble substrates (Figure 10). Colorado pikeminnow located in deep, slow runs were often associated with large substrates (i.e., rubble and boulder).

Diel Observations of Radio-Tagged Colorado pikeminnow

Radio-tagged Colorado pikeminnow displayed both local and long distance movement patterns (e.g. > 1.6 km) over the short diel observation periods (< 12 hr). Seven radio-tagged Colorado pikeminnow showed long distance movement patterns. These fish were first located in areas described as a simple mesohabitat and remained sedentary for 1- to 2-hr. As sunset approached, they left the monitoring site and traveled upstream or downstream distances > 1.6 km until they could no longer be tracked because of rough terrain, poor signal strength, and darkness. For example, two fish (# 25, 26) were located below Upper Disaster Falls in a plunge pool. After 2-hr elapsed, both fish moved upstream through the rapid and traveled an upstream distance of 2.4 km. Another fish (# 01) was located in Browns Park near Vermillion Creek (RK 589.0), and at sunset it moved upstream 1.6 km. But 15-min later, it changed directions and moved downstream towards the Gates of Lodore. Fish 01 traveled downstream 3 km before its signal was lost. In each case, on the following day, fish were found in areas described as complex mesohabitats (e.g. multiple mesohabitats in the monitoring area).

Five Colorado pikeminnow showed local movement patterns and were monitored for more than 12 hr. These fish were located in sites with complex mesohabitats. During the crepuscular period, they engaged in two movement patterns: 1) moving into a riffle and returning back to the eddy; and 2) moving into an eddy and returning back to the run. After the crepuscular period (sunrise or sunset), Colorado pikeminnow were usually sedentary and remained in the local area. Combined night and day observations showed Colorado pikeminnow were located in runs (44%), eddies (36%), and pools (12%; Figure 11). Night and day observations showed Colorado pikeminnow were usually located in similar water depths (*Mann-Whitney U*=975.0; P=0.519) and water velocities (*Mann-Whitney U*=656.5; P=0.119). Day and night observations showed Colorado pikeminnow were found in water depths (< 0.6 m to 1.4 m) (Figure 11). Water velocities ranged from 0.21 to 0.81 m/s (Figure 18). Substrate at these locations was mostly sand (night) and silt/sand (day; Figure 11).

Discussion

Seasonal Use of Browns Park and Lodore Canyon by Colorado Pikeminnow

Radio-tagged Colorado pikeminnow did not establish permanent residency in Lodore Canyon. No Colorado pikeminnow remained in Lodore Canyon to overwinter. Radio-tagged Colorado pikeminnow entered Lodore Canyon from June through mid-August, after peak flows and as water temperatures increased (> 8°C). A few fish (n=3) moved into Lodore Canyon as early as March and left the canyon in June and July, but eventually returned. Colorado pikeminnow moved throughout Lodore Canyon and eight individual Colorado pikeminnow during the three year study even moved into Browns Park but most for only short periods of time.

Radio-tagged Colorado pikeminnow began to move out of Lodore Canyon to their overwintering areas from August through September, and the rest of the fish moved out of the canyon by early October, when water temperatures decreased below 10°C. Most Colorado pikeminnow emigrated distances > 100 km to overwinter in the Jensen-Ouray alluvial reach. One to four radio-tagged Colorado pikeminnow per year emigrated upstream to overwinter in Browns Park, and two fish remained there year round.

Environmental Cues Influencing Movement

Long distance movements displayed by adult Colorado pikeminnow has often been associated with spawning migrations to Yampa and Desolation-Gray canyons (Tyus 1990; Irving and Modde 2000). Colorado pikeminnow have been reported to travel distances > 400 km between pre-spawning and spawning sites, afterwards returning to their former spring locations by late summer or fall to overwinter (Tyus 1990; McAda and Kaeding 1991; Osmundson et al. 1998; Irving and Modde 2000). In this study, Colorado pikeminnow found in Lodore Canyon traveled distances > 100 km to their overwintering habitats in the Jensen-Ouray alluvial reaches.

Tyus and Karp (1989) stated that they believed some complex combination of endogenous and exogenous factors are necessary and that neither discharge nor temperature alone is sufficient to induce spawning migrations or spawning. While we were unable to document spawning of Colorado pikeminnow in Lodore Canyon, the Yampa Canyon has known spawning sites that these fish may have been attempting to migrate to for spawning. More discussion on potential spawning and spawning sites follows later in the discussion.

Although Colorado pikeminnow do not remain in Lodore Canyon year around, Bestgen and Crist (2000) concluded the canyon is an important habitat for prey production and provides an abundant prey base for both subadult and adult Colorado pikeminnow. They indicated maintaining accessible food-rich areas such as Lodore Canyon are doubtless important to growth and conditioning of adult Colorado pikeminnow throughout the upper Colorado River basin. The diversity, abundance, and size distributions of fishes in Lodore Canyon indicates a substantial prey base was available (Bestgen and Crist 2000). The consumption of prey within Lodore Canyon possibly provides these fish the large energy stores required for their migration to overwintering areas in the Jensen-Ouray alluvial reach.

Colorado pikeminnow have been documented to home to previously occupied feeding and winter areas, especially after the spawning season (Wick et al. 1983; Tyus 1984; McAda and Kaeding 1991). Radio-tagged Colorado pikeminnow returned to Lodore Canyon annually (2001 2003) and were re-contacted within 0.8 to 1.6 km from their original point of capture. The use of Lodore Canyon by Colorado pikeminnow may be opportunistic foraging behavior related to bioenergetics efficiency. Colorado pikeminnow were able to remain in Lodore Canyon during warm months and continued to actively feed, but declining water temperatures (< 8°C) in Lodore Canyon in the fall likely prompted Colorado pikeminnow to emigrate to the more energetically efficient alluvial reaches.

Colorado pikeminnow began to move out of Lodore Canyon to their overwintering areas from August through September, and a few fish moved out of the canyon as late as early October. No radio-tagged Colorado pikeminnow remained in Lodore Canyon to overwinter. Flows remained fairly constant

(~ 22.6 m^3/s) in Lodore Canyon, with the exception of fluctuations due to the operation of Flaming Gorge Dam, from May to early June and September. Therefore, flows were not likely the factor to cue the emigration of Colorado pikeminnow out of Lodore Canyon. Water temperatures did not remain constant and by mid September through October descended to 15°C, and by mid-October water temperatures decreased below 10°C. This may be the environmental cue triggering the emigration of Colorado pikeminnow out of the canyon and back to their wintering habitats in the alluvial reaches.

Lodore Canyon may be too hostile of an environment for Colorado pikeminnow to establish residency in the winter. Unfavorable conditions such as supercooled water and frazil ice (slush ice) formation may make overwintering in Lodore Canyon energetically difficult and physically dangerous. Valdez and Masslich (1989) reported that during periods of extreme low air temperatures, the water is supercooled (< 0°C) in Lodore Canyon due to gradients too steep to complete surface ice formation and leads to the formation of frazil ice in the areas of lesser gradient. The abrupt decrease in gradient below Split Mountain Canyon allows the frazil ice to solidify into surface ice. Environmental factors may be affecting winter habitat selection and energy consumption by Colorado pikeminnow. Solid surface ice had the least effect on fish movement (Valdez and Masslich 1989) and was found primarily downstream of the Bonanza Bridge (RK 464.2), where most of the radio-tagged pikeminnow overwintered. Wick and Hawkins (1989) also observed that Colorado pikeminnow in the Yampa River were apparently attracted to frozen over low-velocity areas for the cover and the security the ice cover provided.

Eight radio-tagged Colorado pikeminnow, one to four each year of the study, moved upstream into Browns Park and used this reach both temporarily and year round. Telemetry data from our study showed radio-tagged Colorado pikeminnow utilized Browns Park for more than 24-hr, and a few fish overwintered in Browns Park. Colorado pikeminnow overwintering in Browns Park were > 650 mm TL. Browns Park is an alluvial reach that is likely similar to the Jensen-Ouray reach but environmental or physical constraints may be restricting the ability of more Colorado pikeminnow to occupy this upper reach such as prey abundance, prey size, habitat suitability, thermal regimes, or winter flow fluctuations.

Habitat Use within Lodore Canyon and Browns Park

Ground surveys in Lodore Canyon showed Colorado pikeminnow were predominately found in slow-moving mesohabitats (e.g., deep pools, shallow runs and eddies). These results were similar to results reported by Tyus and Karp (1989) in the Yampa River. We hypothesized mesohabitat complexity and time of day influenced the behavior of Colorado pikeminnow. Daily observations showed when Colorado pikeminnow were located in a simple mesohabitat area (e.g., run or pool), radio-tagged fish were likely to move to areas with complex mesohabitats (e.g., more than one mesohabitat in close proximity to another) after sunset. Colorado pikeminnow located in more complex mesohabitat areas tended to move between mesohabitats but did not leave the general area. Stanford (1994) surveyed Colorado pikeminnow literature and concluded adult Colorado pikeminnow preferred braided and complex channels, where low velocity mesohabitats (e.g., eddies, pools, and slow runs) were abundant. He indicated fish may feed in these environments or simply move into low velocity mesohabitats to avoid the higher flows of the main channel.

In Lodore Canyon, Colorado pikeminnow found in complex mesohabitats remained in these areas during diel observations. It was hypothesized Colorado pikeminnow in Lodore Canyon were feeding in eddies or below riffles, and returned to the runs to rest. Modde et al. (1999) also described movement between different habitats which was linked to feeding behavior. In addition, Colorado pikeminnow found in eddies and runs were located near large substrates (e.g., rubble and boulder). Fish were believed to be staging behind these large substrates to avoid high velocities of the main channel, or observing prey swimming downstream and then ambushing its prey. Stanford (1994) indicated Colorado pikeminnow simply moved around as flows varied, constantly seeking the best energetic return on energy invested while foraging. The large size of Colorado pikeminnow provides for considerable movement, allowing them to efficiently use a highly variable environment (Stanford 1994). Colorado pikeminnow may be maximizing foraging activity in areas of greater prey abundance (Stanford 1994).

Colorado Pikeminnow use of Known Spawning Areas

Radio-tagged Colorado pikeminnow entered Lodore Canyon during the presumptive spawning period, late-June through mid-August (Nesler et al. 1988, Tyus and Karp 1989, Tyus 1990). Colorado pikeminnow congregated in specific locations (i.e., Lake Limestone, and below Winnies Rapid) during the presumptive spawning periods, but no direct evidence (i.e., larval Colorado pikeminnow or direct observation) of spawning or successful reproduction was detected. Although congregating Colorado pikeminnow in itself does not mean fish were engaging in spawning, these Colorado pikeminnow were occupying Lodore Canyon during the presumptive spawning period.

It has previously been hypothesized that Colorado pikeminnow are spawning in other known areas (e.g., Yampa Canyon), and are simply moving into Lodore Canyon to feed and replenish energy reserves before emigrating to their overwintering habitats in the alluvial reaches (McAda and Kaeding 1991; Irving and Modde 2000; Modde and Haines 2003). Most radio-tagged Colorado pikeminnow (n=24) in this study did not migrate up the Yampa River to spawn at Cleopatras Couch, with the possible exception of two fish in 2002 that passed the Yampa telemetry tower. Even after the telemetry station in Yampa Canyon was moved 7.1 km downstream in 2003, only three fish were detected by the tower and did not move upstream to Cleopatras Couch. All Colorado pikeminnow implanted with transmitters were large enough to be mature spawners, yet only two fish migrated to Cleopatras Couch in the Yampa River. We were unable to locate radio-tagged Colorado pikeminnow at spawning localities in Yampa and Gray canyons while conducting aerial surveys. It can be hypothesized radio-tagged Colorado pikeminnow may have reached the spawning sites prior to or after our aerial flights, or may not have spawned each year.

Low flows in the Yampa River may have contributed for the lack of radio-tagged Colorado pikeminnow reaching the spawning bar or attempting to migrate up the Yampa River. In 2002, peak flow in the Yampa River was 98.2 m^3/s, and flows then rapidly declined below 5.7 m^3/s as early as July. Colorado pikeminnow and other fish species (e.g., smallmouth bass) were observed stranded in pools along the Yampa River (M. Fuller, U.S. Fish and Wildlife Service, pers. com.). Colorado pikeminnow may have migrated to other locations above or below known spawning sites. In 2003, the Yampa stationary telemetry tower was relocated above Laddie Park (RK 15.6) because only two radio-tagged Colorado pikeminnow migrated to Cleopatras Couch the previous year (2002). In 2001, tuberculated Colorado pikeminnow were collected near Laddie Park and all individuals were expressing milt (M. Fuller, U.S. Fish and Wildlife Service, pers. com), although this can not be taken as definitive evidence of nearby spawning grounds, unlike if a female producing ova were captured (McAda and Kaeding 1991). Radio-tagged Colorado pikeminnow moved upstream into the Yampa River but remained downstream of Laddie Park. Tyus (1990) also reported some radio-tagged Colorado pikeminnow did not migrate to spawning areas each year because fish were immature, non-spawners, or moved to other locations to spawn. Two fish in Browns Parks never migrated downstream, which indicated individual Colorado pikeminnow may not spawn each year. These two Colorado pikeminnow were not immature.

Colorado State University established larval drift stations above the Yampa River confluence in Lodore Canyon in the mid-1990's and 2002, and yielded no larval Colorado pikeminnow from the Green River, but they collected larval Colorado pikeminnow from the Yampa River (K. Bestgen, Colorado State University, pers. com.). The presence of larval Colorado pikeminnow would provide stronger evidence to support the hypothesis of potential spawning activity in Lodore Canyon.

Although drifting larvae would be more indicative of spawning activity, the absence of drifting larvae does not exclude the possibility that spawning may have been attempted by Colorado pikeminnow but was not successful. There are likely many complex environmental and biological influences effecting Colorado pikeminnows ability to spawn (Tyus and Karp 1989, Nesler et al. 1988). The current conditions in Lodore Canyon may not be adequate for these fish to successfully spawn.

Current flow regimes in Lodore Canyon may be effecting the ability of Colorado pikeminnow to spawn. Nesler et al. (1988) hypothesized that flow spikes near baseline flows in the Yampa River acts as a recurring environmental cue to adult Colorado pikeminnow to initiate the spawning process of egg deposition and fertilization. While Nesler et al. (1988) state that the minimum magnitude of flow spike is unknown (spikes of 14 m^3/s or greater represented 60 % of spikes recorded), Lodore Canyon experienced little to no flow spikes from 2000 to 2003, with the exception of 2001. In 2001, very minor flow spikes occurred during the month of June, but not during the most common spawning period for Colorado pikeminnow and likely of insufficient magnitude to act as a spawning cue. Flows in Lodore Canyon are relatively constant from the beginning of June through August. Water temperature is a known environmental cue to induce spawning , but temperatures in Lodore Canyon are within the known parameters for successful spawning of Colorado pikeminnow, and therefore we do not believe that it is adversely affecting reproductive success.

As put forth by others (McAda and Kaeding 1991; Stanford 1994), our results suggest the possible existence of more spawning areas which have not been recognized. Colorado pikeminnow may be using alternative spawning sites at least opportunistically, when conditions are favorable. Many of the sites where Colorado pikeminnow were congregating (Lake Limestone and below Winnie Rapid) have physical characteristics similar to known spawning sites. Main features observed included eddies or pools which were located in close proximity to chutes and steep riffles with very loose cobble substrates (Tyus 1990; Miller and Ptacek 2000).

CONCLUSIONS

Colorado pikeminnow do not overwinter in Lodore Canyon. Migration into Lodore Canyon from the Jensen-Ouray alluvial reach begins in spring and summer. Colorado pikeminnow resided in

Lodore Canyon from 1 to 132 d. Colorado pikeminnow emigrate out of Lodore Canyon to their overwintering areas from August through September, and all radio-tagged fish were out of the canyon by early October, when water temperatures decreased below 10°C.

Browns Park is an alluvial reach that is utilized by Colorado pikeminnow seasonally and to a lesser degree, year round. A few Colorado pikeminnow did overwinter in Browns Park. Certain environmental or physical constraints may be restricting Colorado pikeminnow from utilizing this area.

Long distance migration displayed by adult Colorado pikeminnow has often been associated with spawning migrations to the Yampa Canyon or to the other known spawning sites in Desolation/ Grays Canyon. Our hypothesis is that Colorado pikeminnow may be migrating directly to Lodore Canyon to attempt spawning as so few radio tagged Colorado pikeminnow tried to migrate up the Yampa Canyon. There may be adequate environmental cues to induce spawning migrations, but conditions in Lodore Canyon may be inadequate for Colorado pikeminnow to successfully spawn. Movement out of Lodore Canyon from August through September was believed to be associated with decreasing water temperatures. After water temperatures dropped below 8°C, no radio-tagged Colorado pikeminnow occupied Lodore Canyon. Colorado pikeminnow are known to home to previously occupied feeding and wintering areas, and this is the most likely reason for migration back to the alluvial reach. Lodore Canyon may be too hostile of an environment for Colorado pikeminnow to establish residency in the winter.

Radio-tagged Colorado pikeminnow were located in slow-moving mesohabitats (e.g., runs, eddies and pools). Daily observations showed fish were sedentary. Diel observations showed radio-tagged pikeminnow were found in simple mesohabitats but moved downstream or upstream just prior to sunset. Colorado pikeminnow found in complex mesohabitats (e.g., more than one mesohabitat present in the monitoring site), remained within the area but moved between mesohabitats. It was hypothesized Colorado pikeminnow were utilizing these complex mesohabitats to feed and rest.

Colorado pikeminnow may be attempting to spawn at certain locations in Lodore Canyon at least opportunistically and when environmental conditions are favorable. However, no direct observation of spawning activity was observed and larval Colorado pikeminnow have not been collected in Lodore Canyon. In 2001, two radio-tagged Colorado pikeminnow migrated up the Yampa River to the spawning bar at Cleopatras Couch, no other radio-tagged fish migrated up the Yampa Canyon to the known spawning site.

RECOMMENDATIONS

Continue to monitor larval drift stations in Lodore Canyon during the suspected spawning period of Colorado pikeminnow; and potentially establish additional larval drift stations below suspected spawning sites (e.g., Lake Limestone and Winnies Rapid) in Lodore Canyon.

Sample intensively at suspected potential spawning sites using underwater cameras, scuba and snorkeling gear, angling, and trammel nets to determine the presence of spawning activity and evaluate the physical appearance of Colorado pikeminnow (i.e., primary and secondary sexual characteristics).

Conduct winter habitat study on Colorado pikeminnow in Browns Park to evaluate movement, habitat use, habitat availability, and potentially determine factors (i.e., biological and physical) that may be restricting more Colorado pikeminnow from utilizing Browns Park.

Re-evaluate the use of Lodore Canyon and Browns Park when base flows exceed 28.3 m^3/s to determine the total number of Colorado pikeminnow presence, the duration fish remain in the canyon, local movement patterns, habitat use, long distance movement, and environmental factors contributing to movement.

Consider re-evaluating dam operations to mimic a natural flow regime including flow spikes and evaluate potential changes to thermal regime and to suspected spawning habitat. During peak flows in the spring allow water temperatures to increase with increasing flows, which may potentially restore reproduction by endangered fishes such as Colorado pikeminnow. In addition, higher peak flows may scour out and remove fine sediments at potential spawning localities in Lodore Canyon and enhance spawning chances by Colorado pikeminnow.

Further evaluation of response of the fish community in Lodore Canyon to the soon to be implemented Flaming Gorge Flow recommendations is needed. The effects of the new dam operations on Colorado pikeminnow, and other fish species, needs to be monitored, followed by an evaluation of wether dam operations need to be further modified.

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Mention of trade names or commercial products does not constitute endorsement or recommendations for use by the authors, the Fish and Wildlife Service, U. S. Department of the Interior, or members of the Recovery Implementation Program.

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Table 1. Aerial, sampling, and ground survey dates conducted from 2000 to 2003.

Aerial Flights

Year	Dates	N	Aerial Coverage
2000	7/1, 8/17, 11/13	3	DINO*, Browns Park, Alluvial Reach
2001	5/6, 6/20, 7/13, 7/14, 12/13, 12/16	6	DINO, Browns Park, Alluvial Reach, Desolation-Gray canyons
2002	6/20, 8/18, 10/18	3	DINO, Browns Park, Alluvial Reach, Duchesne River
2003	3/21, 10/22	2	DINO, Browns Park, Alluvial Reach, White River, Duchesne River

* DINO - refers to Dinosaur National Monument and includes the following areas: Lodore Canyon, Yampa Canyon, Echo Park, Whirlpool Canyon, Island Park, Spilt Mountain

Sampling and Ground Surveys Dates in Lodore Canyon and Browns Park

Year	Dates	N	Location	Total Sampling Days	Gear Type
2000	4/20, 8/1, 8/2, 8/22, 8/23, 9/15	6*	Lodore Canyon	6	EL / AN
2000	6/11-13, 8/3-4	2	Browns Park	5	EL
2001	5/24-25, 7/10-12, 8/22-24, 8/28-31, 10/18	5	Lodore Canyon	13	AN
2002	6/25-28, 7/23-26, 8/12-16, 8/26-30, 9/23-27	5	Lodore Canyon	23	EL / AN
2002	7/02-03, 8/20-8/22	2	Browns Parks	4	AN
2003	5/19-22, 6/30-7/03, 7/21-24, 8/11-13, 9/15-17	5**	Lodore Canyon	18	AN / EL

* Only river reaches 4 and 5 were sampled in 2000.

** Minimal sampling was conducted because all transmitters had been implanted into Colorado pikeminnow. Secondly, water turbidity caused angling to be ineffective.

Table 2. Gear type, number of trips, sampling location, and total number of Colorado pikeminnow collected in each river reach from 2000 to 2002. Average total length and size distribution were summarized for sampling location.

Year	# of Trips	Location	Gear Type	# CS Collected per River Reach 1	2	3	4	5	Total CS Collected	Average TL mm	Range TL mm
2000	6	Lodore Canyon*	Angling	-	-	-	1	6	9	568	455 - 619
			Electrofishing	-	-	-	0	2			
2000	2	Browns Park	Electrofishing	0	-	-	-	-	0	----	----
2001	5	Lodore Canyon	Angling	0	2	4	3	7	16	600	415 - 820
2002	5	Lodore Canyon	Angling	0	3	17	6	25	52	553	380 - 745
			Electrofishing	0	1	0	0	0			
2002	2	Browns Park	Angling	0	-	-	-	-	0	---	----

* Only river reaches 4 and 5 were sampled in 2000.

Table 3. Background information on adult Colorado pikeminnow collected in Lodore Canyon, Colorado and implanted with transmitters from 2000–2002.

Year	Code	Frequency	Implant Date	TL (mm)	WT (g)	RK	Transmitter Duration (d)
2000							
	24	149.740	08/02/00	630	1766	557.5	824
	25	149.740	08/23/00	579	1515	563.5	824
	26	149.760	04/20/00	701	2890	559.1	824
	27	149.760	08/22/00	585	1500	562.0	824
	28	149.740	08/01/00	465	830	560.8	367
	29	149.740	08/01/00	522	1035	562.2	367
	31	149.760	08/22/00	544	1000	562.2	367
2001							
	1	149.740	07/10/01	653	2784	578.7	824
	2	149.740	05/24/01	695	2844	565.2	824
	30	149.760	07/10/01	699	2278	578.7	824
	22	149.740	07/10/01	820	1808	578.7	824
	42	149.740	08/23/01	696	3034	569.9	912
	43	149.740	08/23/01	644	2264	569.9	912
	44	149.740	10/18/01	596	1501	559.1	912
	45	149.740	08/31/01	720	2742	559.1	912
2002							
	13	149.740	06/26/02	582	1900	572.8	912
	14	149.740	06/27/02	641	1760	559.1	912
	12	149.740	07/24/02	718	2604	579.2	912
	15	149.740	07/24/02	685	2470	576.0	912
	41	149.760	07/24/02	745	3176	576.0	912
	16	149.760	08/13/02	665	2615	578.7	912
	17	149.760	08/13/02	685	2340	578.7	912
	42	149.760	08/13/02	600	1980	578.7	912
	45	149.760	08/14/02	590	1829	571.8	912
	44	149.760	08/27/02	625	2572	576.0	912
	43	149.760	08/27/02	722	3160	581.6	912
	117	149.760	09/23/02	515	1137	581.2	457
	118	149.760	09/23/02	607	1654	581.2	457
	113	149.740	09/26/02	587	1467	560.9	457
	110	149.740	09/26/02	538	986	560.7	457
	114	149.740	09/26/02	521	978	559.1	457

Table 4. Dates and river conditions of when radio-tagged Colorado pikeminnow emigrated out of Lodore Canyon and the number of days Colorado pikeminnow occupied Lodore Canyon from 2000 to 2003.

Year	**N**	**Emigration Date**		**Occupancy (d)***		**Discharge (m^3/s)**		**Temperature (°C)**	
		Mean	**Range**	**Mean**	**Range**	**Mean**	**Range**	**Mean**	**Range**
2000	7	Sept 15	Aug 8–Oct 25	26	6–64	33.9	28.9–36.5	14.8	9.7–12.1
2001	11	Sept 13	July 4–Oct 23	11	1–77	23.2	22.2–23.7	15.1	8.1–22.2
2002	25	Sept 7	Jun 28–Oct 22	19	1–128	24.0	22.7–29.4	16.0	9.0–21.4
2003	13	Sept 12	Aug 11–Oct 11	53	20–90	23.0	23.0–23.2	14.7	11.6–21.4

N = number of radio tagged Colorado pikeminnow in Lodore Canyon

*= refers to the number of days radio-tagged Colorado pikeminnow remained in Lodore Canyon.

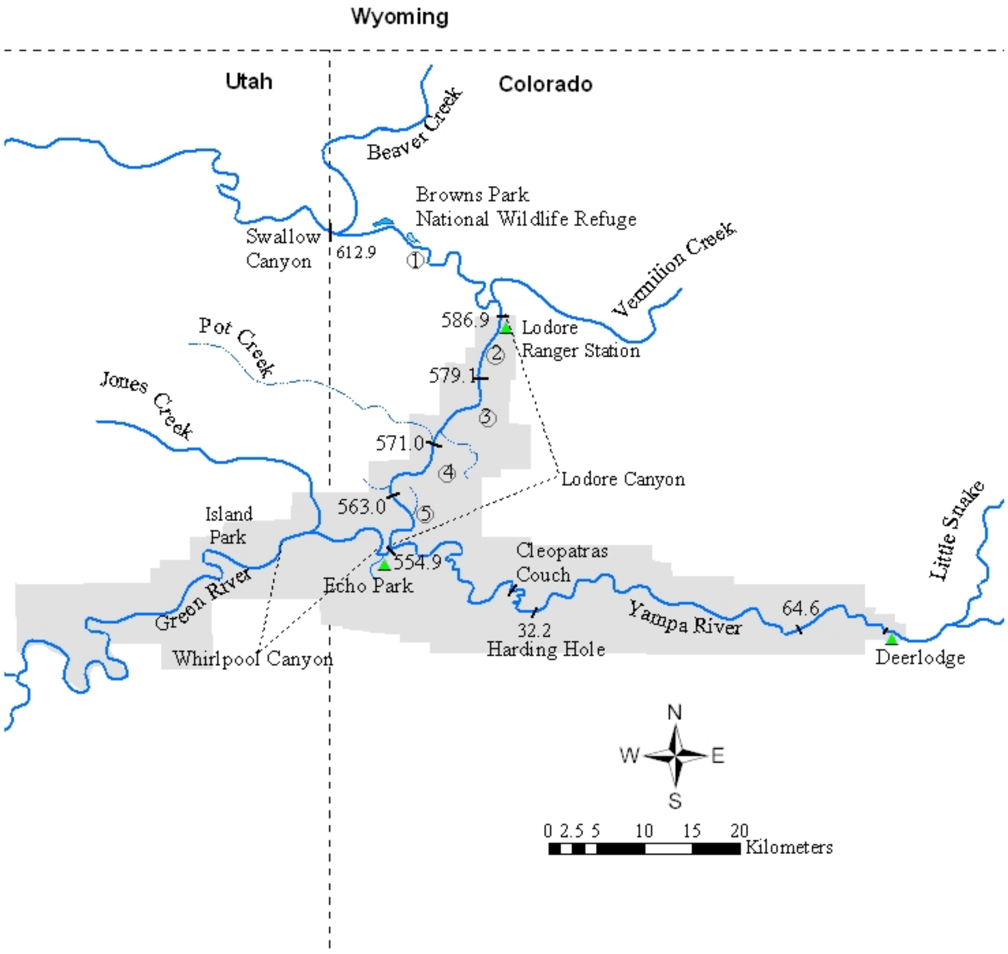

Figure 1. Map of the 57.9 km study area on the Green River which includes Browns Park and Lodore Canyon. Browns Park and Lodore Canyon are located in northwestern Colorado.

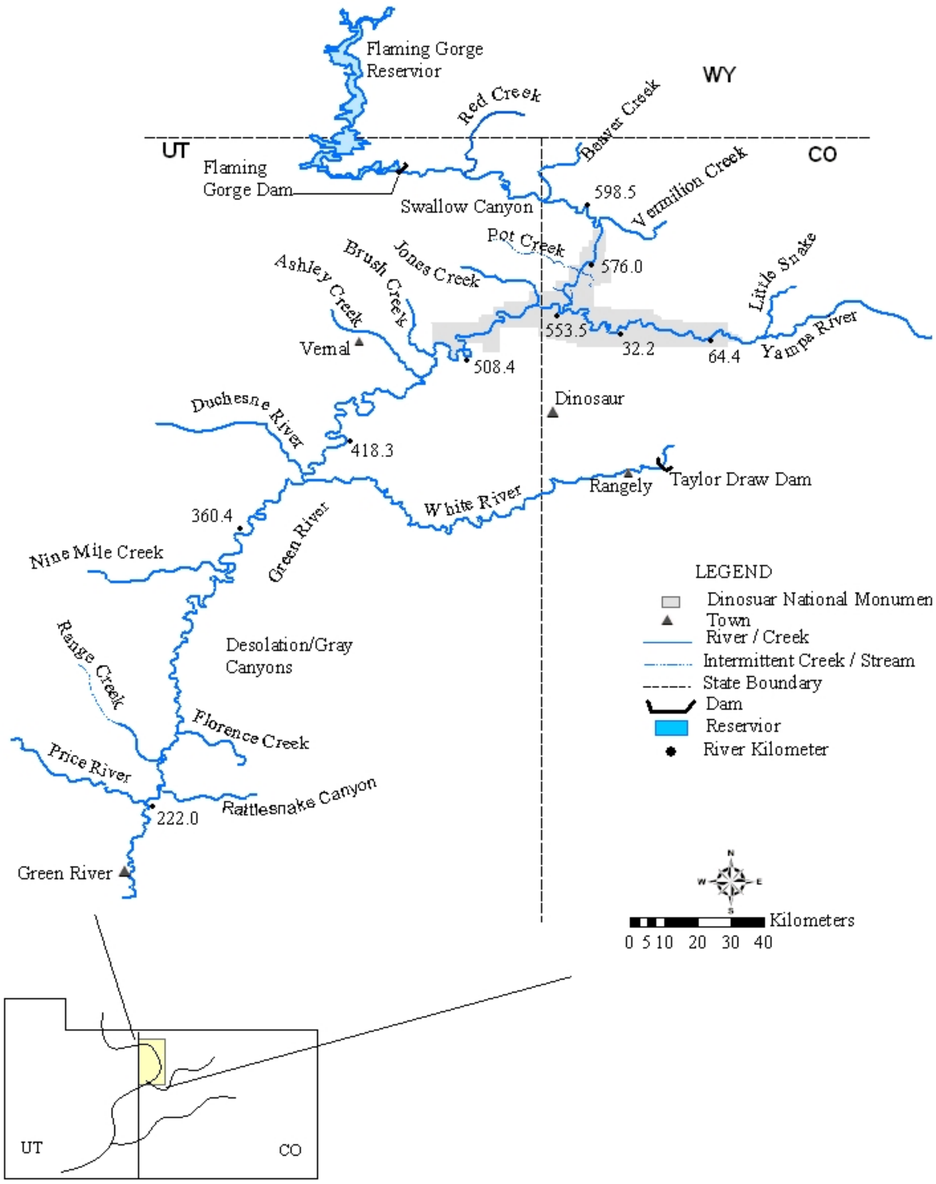

Figure 2. Aerial coverage for flights conducted in the Green River subbasin between 2000–2003. Flight paths included lower Yampa and Duchesne rivers, White River between Taylor Draw Dam and confluence, and Green River from Swallow Canyon downstream to Three Fords Rapid.

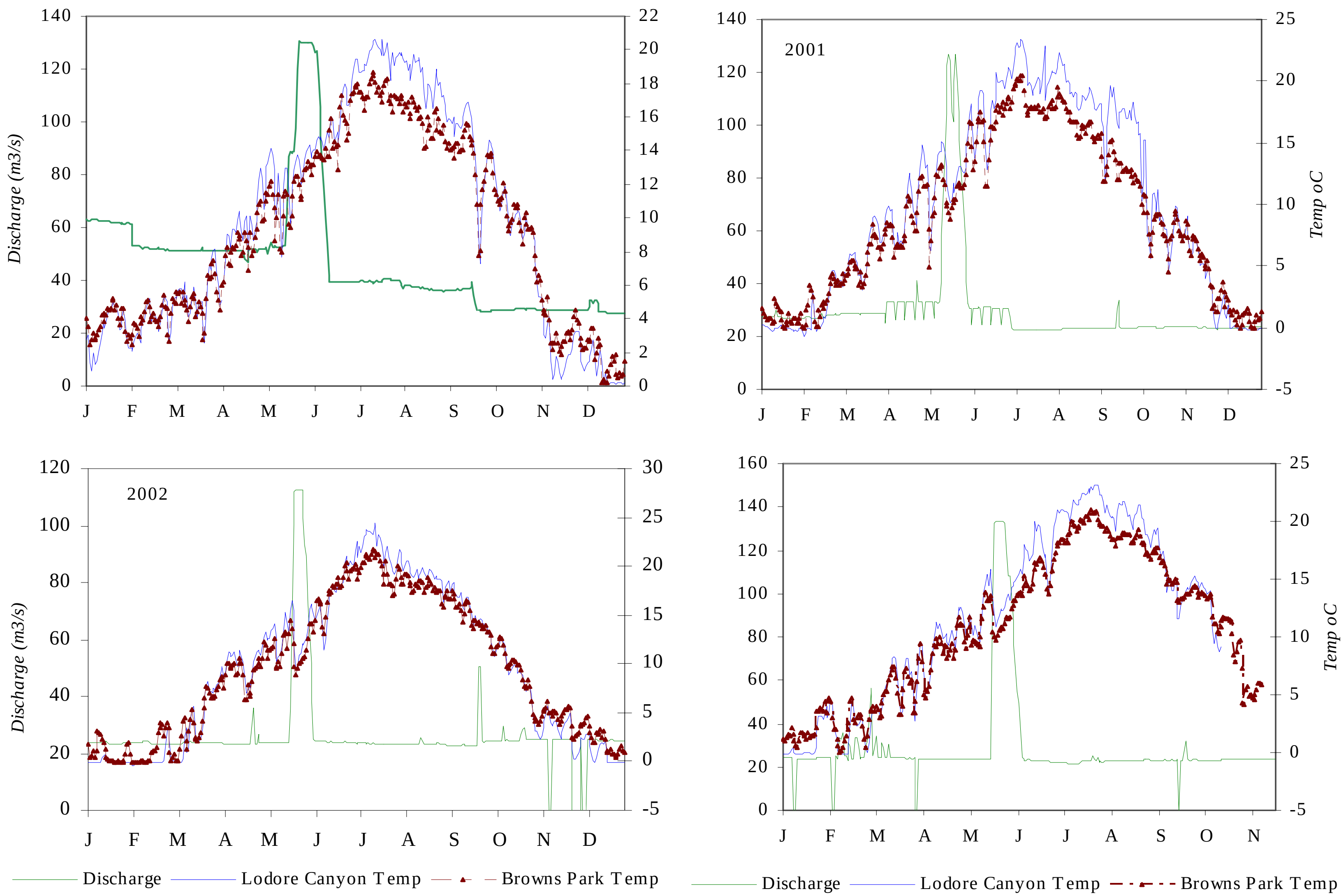

Figure 3. Average daily discharge and daily water temperatures for the Green River below Flaming Gorge Dam, 2000–2003.

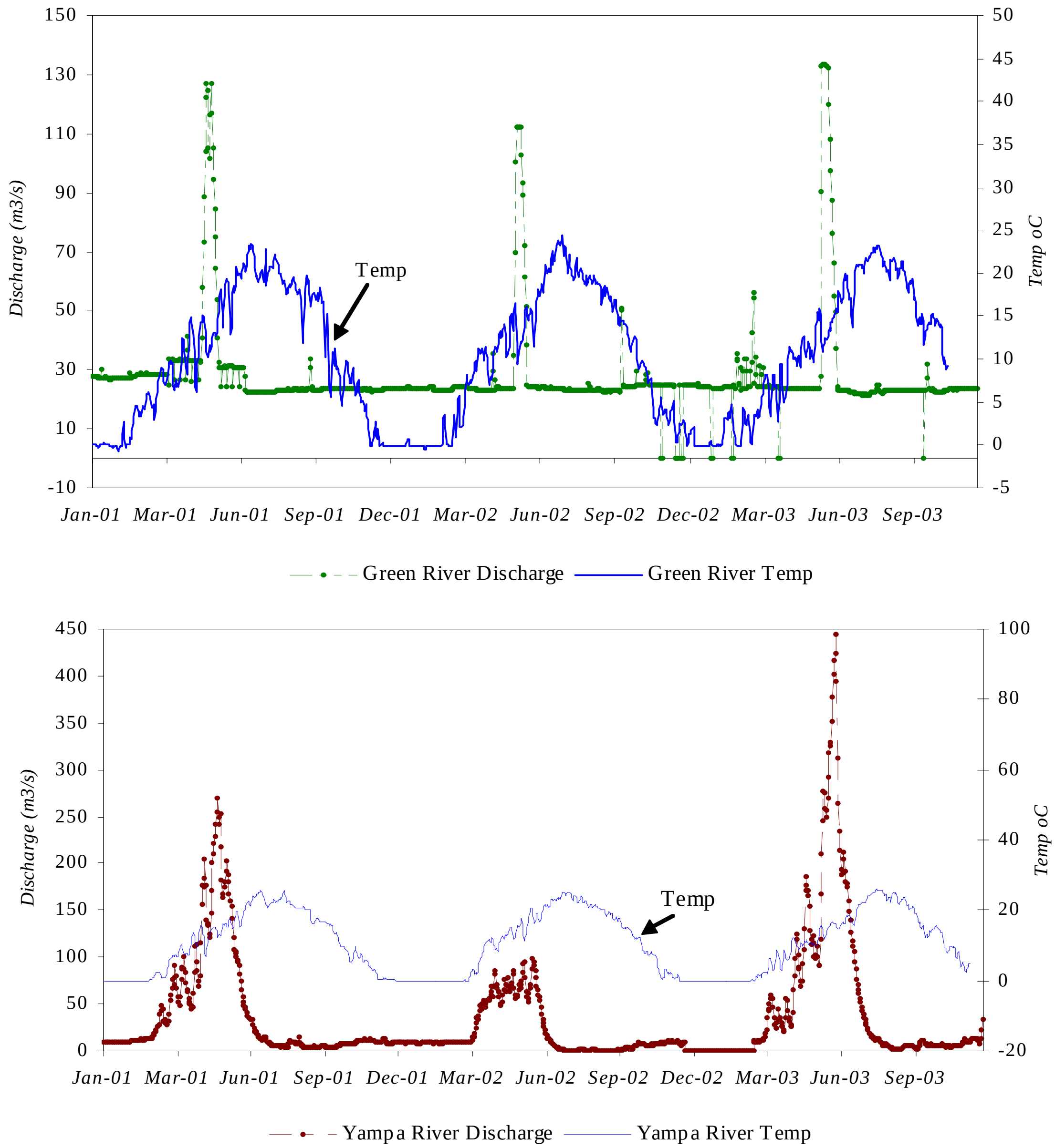

Figure 4. Comparison of mean daily discharge and river temperatures of the Green and Yampa rivers from 2001–2003.

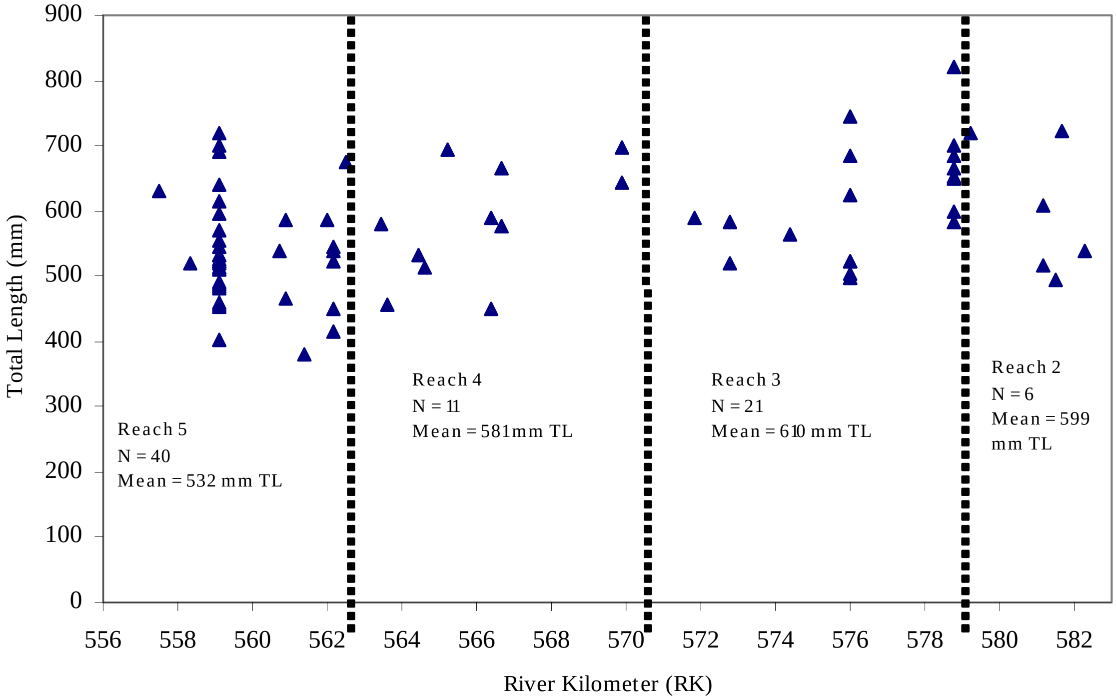

Figure 5. Total number and size distribution of Colorado pikeminnow collected in four reaches of the Green River in Lodore Canyon, Colorado from 2000–2002.

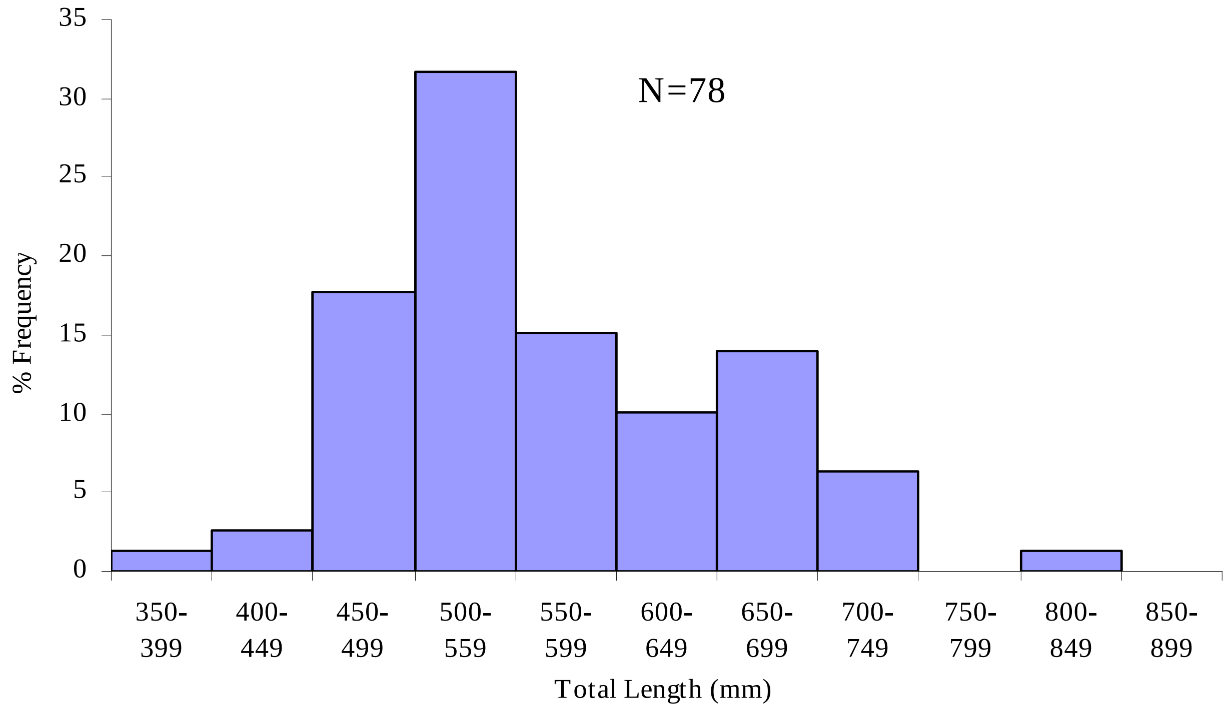

Figure 6. Length frequency histogram for Colorado pikeminnow collected in Lodore Canyon, Colorado from 2000–2002.

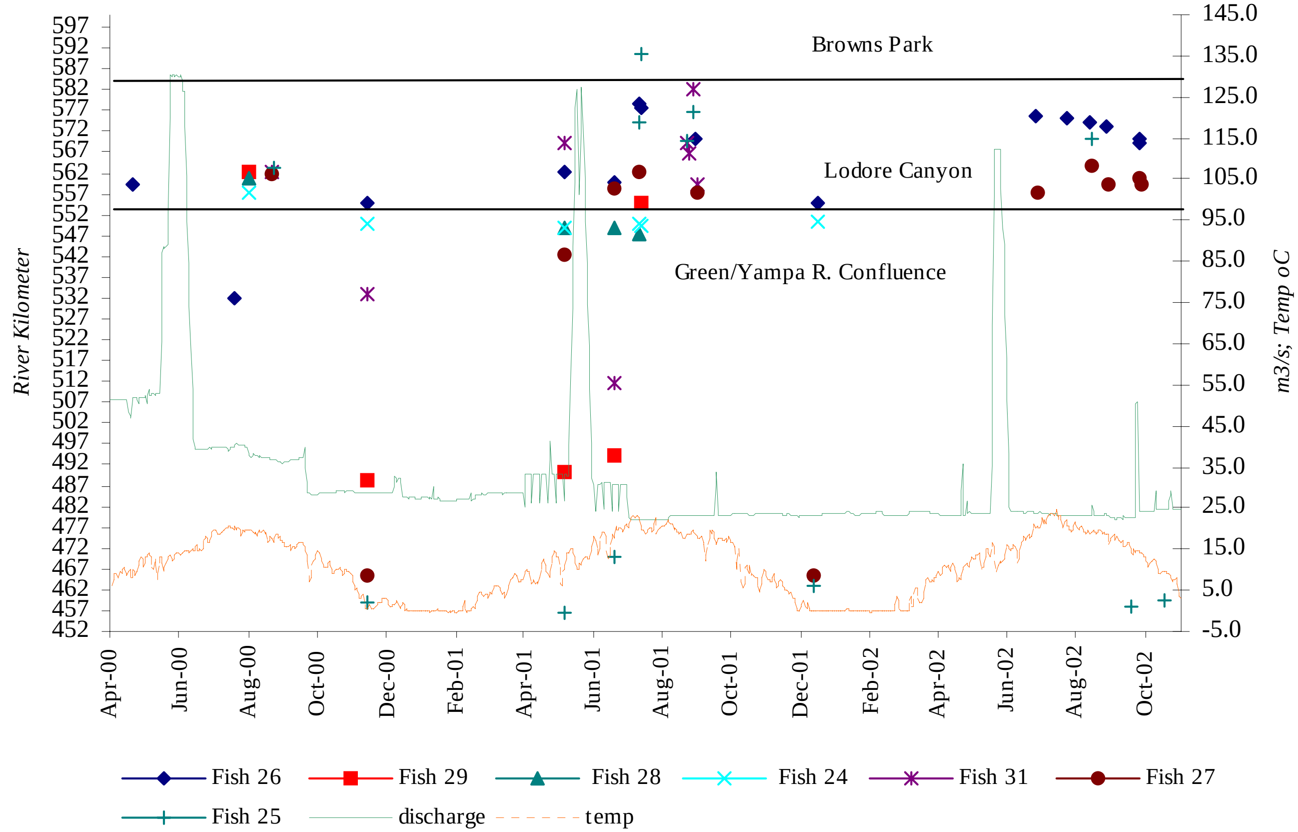

Figure 7. Aerial and ground survey locations of Colorado pikeminnow implanted with transmitters in 2000 plotted against Green River hydrograph (i.e., Greendale gage #09234500) and water temperatures (i.e., Lodore Canyon). Each symbol represents a fish and each point a contact. A symbol located on the Green/Yampa R. confluence line (RK 554.9) represents a radio-tagged fish found in Yampa Canyon.

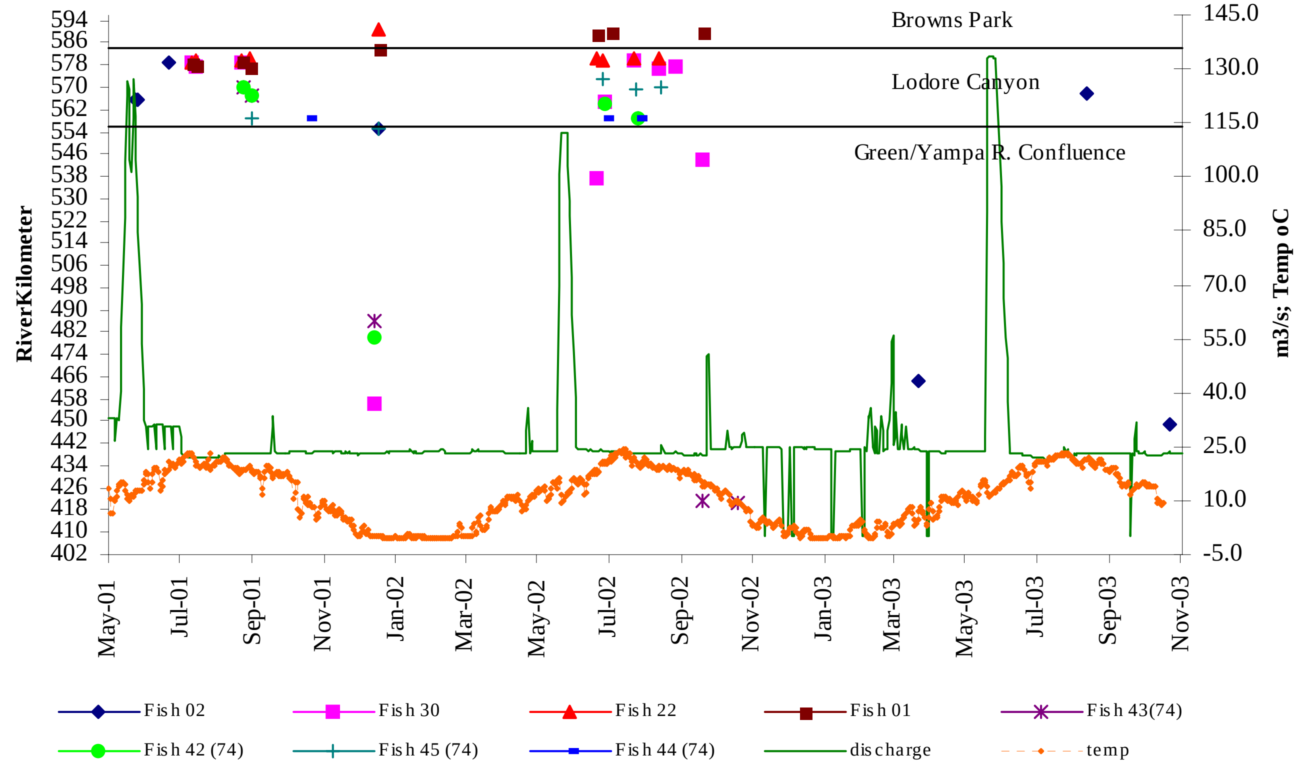

Figure 8. Aerial and ground survey locations of radio-tagged Colorado pikeminnow implanted in 2001 plotted against Green River hydrograph (i.e., Greendale gage #09234500) and water temperatures (i.e., Lodore Canyon). Each symbol represents a fish and each point a contact. A symbol located on the Green/Yampa R. confluence line (RK 554.9) represents a radio-tagged fish found in Yampa Canyon.

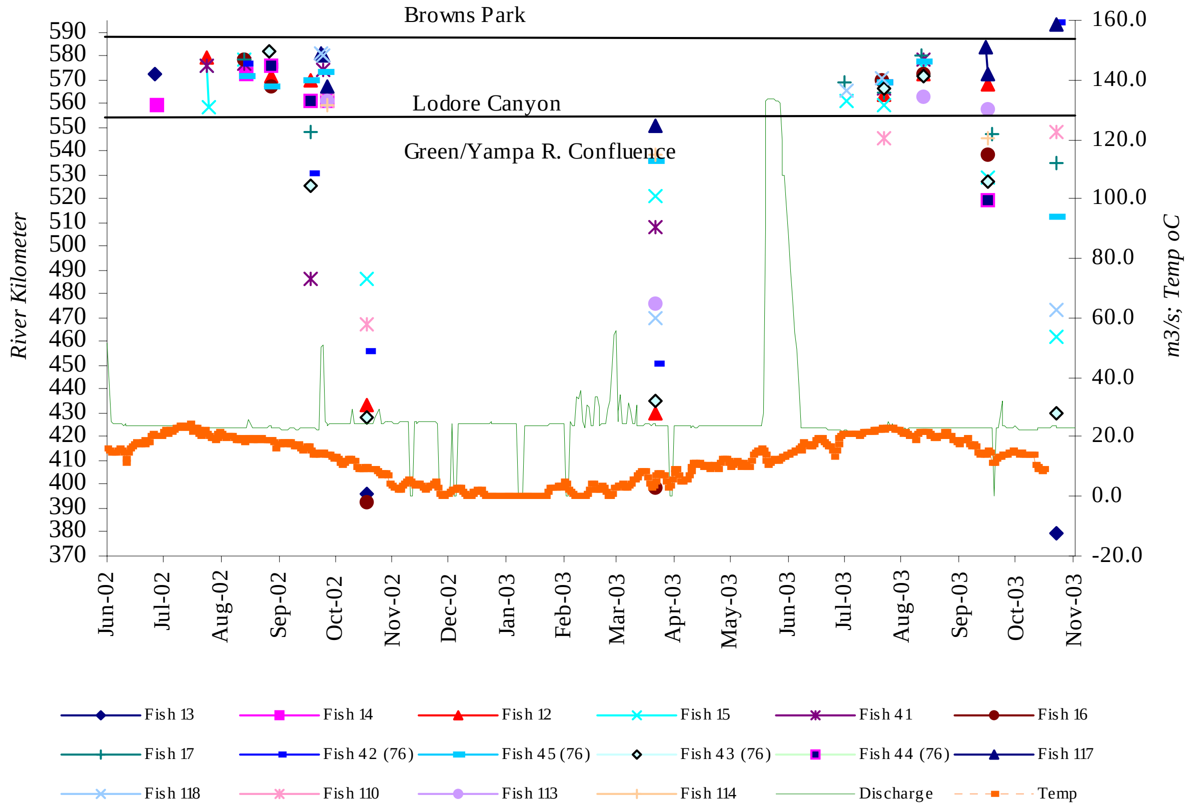

Figure 9. Aerial and ground survey locations of Colorado pikeminnow implanted in 2002 plotted against Green River hydrograph (i.e., Greendale gage #09234500) and water temperatures (i.e., Lodore Canyon). Each symbol represents a fish and each point a contact. A symbol located on the Green/Yampa R. confluence line (RK 554.9) represents a radio-tagged fish found in Yampa Canyon.

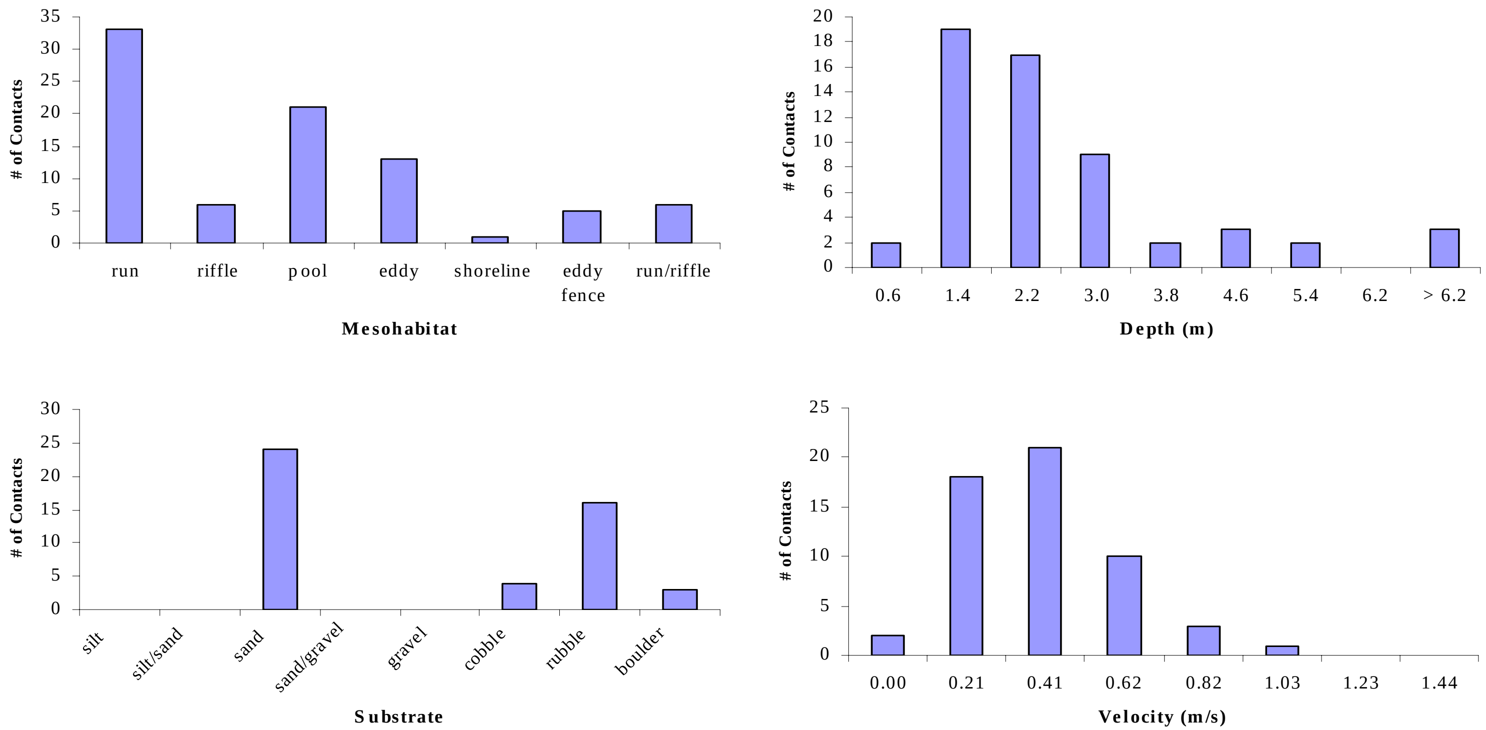

Figure 10. Daily mesohabitats and microhabitats recorded for radio-tagged Colorado pikeminnow in Lodore Canyon, Colorado.

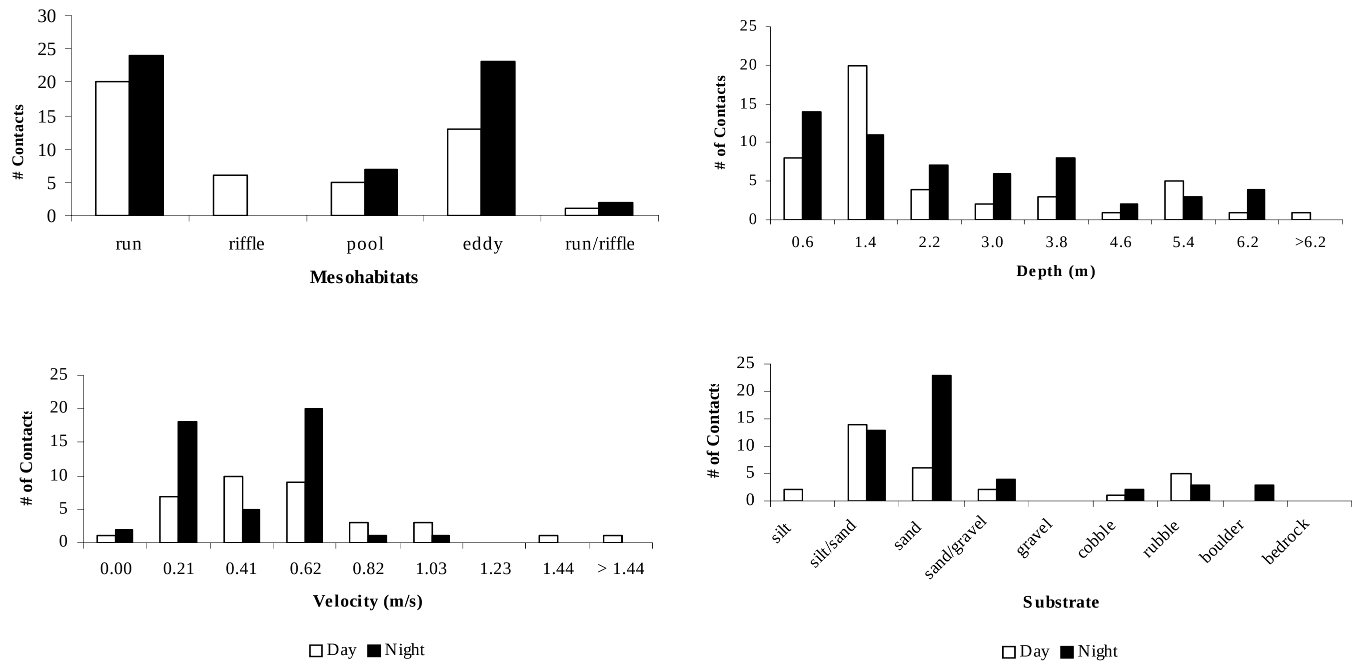

Figure 11. Mesohabitats and microhabitats recorded for radio-tagged Colorado pikeminnow during the day (white bars) and at night (black bar) in Lodore Canyon, Colorado.

APPENDICES

Appendix 1. Capture and recapture history of Colorado pikeminnow collected in Lodore Canyon, Colorado from 2000 to 2003.

RECAPTURED IN 2000

	Date	River	PIT-TAG	Code	Recap	TL (mm)	Weight (g)	RK	Distance Traveled
1	5/2/2000	GR	5124094224	29	N	530	1139	535.2	
	8/1/2000	GR			Y	522	1035	562.2	
									27.0
2	5/15/1998	YA	223F6C784F	26	N	657	2615	0.2	
	4/20/2000	GR			Y	701	2890	559.1	
3	5/18/2000	GR	51240A455A	28	N	461	677	533.1	
	8/1/2000	GR			Y	465	830	560.9	
									27.8
4	4/11/2000	GR	512B125E0B	24	N	632	1850	530.6	
	8/2/2000	GR			Y	630	1766	557.5	
									26.9

RECAPTURED IN 2001

	Date	River	PIT Tag	Code	Recap	TL	Weight	RK	Distance Traveled
5	5/14/1998	GR	22404D3D45	---	N	669	2232	528.1	
	7/10/2001	GR			Y	699	2278	578.8	
6	5/5/1998	GR	2242356D78	---	N	637	2016	479.8	
	8/23/2001	GR			Y	696	3034	569.9	
7	4/9/2001	GR	416303555C	---	N	430	674	350.0	
	5/16/2001	GR			Y	436	725	361.5	
	7/12/2001	GR			Y	450	701	562.2	
									212.2
8	5/9/2000	GR	512418040B	---	N	405	471	395.0	
	5/16/2001	GR			Y	430	581	495.3	
	8/31/2001	GR				459	719	559.1	
									63.9
9	4/12/2000	GR	512D10033F	---	N	471	838	528.7	
	8/31/2001	GR			Y	511	966	559.1	

RECAPTURED IN 2002

	Date	River	PIT Tag	Code	Recap	TL	Weight		Distance Traveled
10	5/10/2000	WH	5124082369	---	N	450	670	9.2	
	8/29/2002	GR			Y	533	1040	559.1	
11	4/24/2001	GR	5127645802	---	N	505	940	534.7	
	7/25/2002	GR			Y	512	906	559.1	

12	6/14/2000	GR	5127647922	---	N	475	807	424.8	
	8/13/2002	GR			Y	524	1029	576.0	
13	5/18/2002	YA	1F200B5C5A	---	Y	508	1300	117.5	
	8/15/2002	GR			Y	513	925	564.6	
									127.1
14	5/17/1996	GR	1F40402E33	---	N	445	755	433.0	
	5/19/2000	GR			Y	510	1040	487.2	
	7/25/2002	GR			Y	531	1031	559.1	
15	5/16/1996	GR	1F41663208	---	N	255	135	71.1	
	4/24/2001	YA			Y	508	1000	169.6	
	5/12/2001	YA			Y	512	1150	166.4	
	8/15/2002	GR			Y	544	1077	559.1	
16	5/12/2002	GR	423E7F2F4F	---	N	553	1360	298.5	
	7/25/2002	GR			Y	555	1101	559.1	
									260.7
17	5/29/2001	YA	5126534D25	---	N	505	1150	155.4	
	5/29/2002	YA			Y	516	1150	165.7	
	7/25/2002	GR			Y	514	975	559.1	
									169.7
18	5/12/2001	YA	51265B6C52	---	N	489	950	154.5	
	5/30/2001	YA			Y	484	850	153.2	
	4/28/2002	YA			Y	530	1350	154.9	
	8/15/2002	GR			Y	523	1094	559.1	
									159.0
19	7/11/2002	GR	5138661B68	---	N	482	756	523.2	
	8/29/2002	GR			Y	487	740	559.1	
									35.9
20	4/21/2002	GR	53120D314C	---	N	424	740	183.4	
	8/29/2002	GR			Y	452	700	559.1	
									375.7
21	5/21/2001	GR	532566451A	110	N	525	963	445.2	
	8/15/2002	GR			Y	530	955	559.1	
	9/26/2002	GR			Y	538	986	560.7	
									1.6
22	10/18/2001	GR	53261A5849	44	N	596		558.5	
	7/25/2002	GR			Y	691	1294	559.1	
23	4/19/2001	GR	53262E7655	---	N	475	811	310.4	
	5/8/2001	GR			Y	471	851	313.6	
	7/25/2002	GR			Y	522	1023	559.1	
24	6/3/2002	GR	532630175C	---	N	658	2345	506.2	
	8/13/2002	GR			Y	665	2615	578.8	

72.6

25	8/22/2000	GR	5326654B12	---	N	415	N.A.	562.2
	8/13/2002	GR			Y	496	980	576.0
26	5/31/2001	GR	532667360E	---	N	540	1187	485.8
	8/14/2002	GR			Y	576	1515	566.7
27	5/1/2001	GR	53267D0847	---	N	485	883	529.4
	5/14/2001	GR			Y	490	932	533.2
	7/24/2002	GR			Y	503	941	576.0
28	5/14/1998	GR	2242191809	---	N	505	1050	534.2
	8/16/2002	GR			Y	520	1240	558.3
29	5/6/1999	GR	5130531264	---	N	625	1850	534.7
	8/13/2002	GR			Y	685	2340	578.8
30	6/6/1996	YA	1F61576445	---	N	599	2068	0.2
	8/27/2002	GR			Y	625	2572	576.0
31	6/26/1996	DU	1F62653565	---	N	630	2131	0.2
	7/24/2002	GR			Y	745	3176	576.0
32	5/14/1998	GR	22402C051C	---	N	374	399	458.6
	8/29/2002	GR			Y	490	800	559.1
33	5/5/1998	GR	22411C3922	---	N	446	633	184.9
	8/13/2002	GR			Y	600	1980	578.8
34	6/17/1999	GR	512B1C0058	---	N	490	1920	480.4
	8/15/2002	GR			Y	571	1346	559.1
35	5/1/1992	GR	7F7D134C1B	---	N	N.A.	N.A.	0.0
	6/24/2002	GR			Y	650	2348	578.8
36	5/11/1999	GR	513021486C	13	N	525	1190	473.0
	6/26/2002	GR			Y	582	1900	572.8
37	5/22/1996	GR	1F743D624E	15	N	575	1625	481.1
	6/5/1996	GR			Y	569	1425	494.1
	7/24/2002	GR			Y	685	2470	576.0
38	5/15/2001	GR	5319753421	14	N	652	2291	377.8
	6/27/2002	GR			Y	641	1760	559.1
39	6/14/2000	GR	5127647922	---	N	475	807	424.8
	6/28/2002	GR			Y	523	1260	559.1

Appendix 2. Aerial and ground survey locations of radio-tagged Colorado pikeminnow found in 2000 and 2001. Transmitter code, contact date, and RK location are listed for each radio-tagged fish implanted in 2000 and 2001. Abbreviations are as follows: A - aerial survey, G- ground survey, N.A.- transmitter is not active, N.L. - fish not located, M - Mortality, and Y - Yampa River.

				2000					**2001**			
Fish Code	Initial Capture Site (RK)	Initial Capture Date	7/7^{A}	8/17^{A}	11/13^{A}	5/6^{A}	6/20^{A}	7/10-7/12^{G}	7/13^{A}	8/21-8/24^{G}	8/28-8/31^{G}	12/13^{A} 12/16^{A}
24	557.5	8/2/2000	---	557.2	549.6	548.7	N.L.	553.0	549.5	M	M	M
25	563.4	8/23	---	---	459.2	455.8	469.8	574.2	590.5	569.9	576.7	462.7
26	559.1	4/20	532.1	575.5	0.8^{Y}	562.2	559.9	578.6	577.6	N.L.	570.1	0.8^{Y}
27	562.0	8/22	---	---	465.3	542.2	558.3	562.2	N.L.	N.L.	557.2	465.3
28	560.9	8/1	---	N.L.	N.L.	548.8	548.7	547.2	N.L.	M	M	M
29	562.2	8/1	---	561.0	488.4	490.1	494.0	N.L.	2.7^{Y}	N.A.	N.A.	N.A.
31	562.2	8/22	---	---	533.2	569.3	511.7	N.L.	N.L.	569.3	582.3 559.1	N.A.
1	578.7	7/10/2001	---	---	---	---	---	---	578.4	579.4	577.1	584.1
2	565.2	5/24	---	---	---	---	579.2	N.L	N.L.	N.L.	N.L.	0.8^{Y}
30	578.7	7/10	---	---	---	---	---	---	577.6	579.2	N.L.	455.7
22	578.7	7/10	---	---	---	---	---	---	580.0	579.4	580.5	590.8
42^{740}	569.9	8/23	---	---	---	—	—	—	—	—	568.3	479.8
43^{740}	569.9	8/23	---	---	---	---	---	---	—	—	568.3	486.1
44^{740}	559.1	10/18	---	---	---	---	---	---	---	---	---	N.L.
45^{740}	559.1	8/31	---	---	---	---	---	---	---	---	---	2.7^{Y}
# of Active Transmitters			1	3	7	7	8	8	11	8	10	11

Appendix 3. Aerial and ground survey locations of radio-tagged Colorado pikeminnow found in 2002. Transmitter code, contact date, RK location are listed for each radio-tagged fish implanted in 2000, 2001, and 2002. Abbreviations are as follows: A - aerial survey, G- ground survey, N.A.- transmitter is not active, N.L. - fish not located, M - Mortality, and Y - Yampa River.

			2002								
Fish Code	Initial Capture Site (RK)	Initial Capture Date	6/20[A]	6/25-6/28[G]	7/02-7/03[G]	7/23-7/26[G]	8/12-8/16[G]	8/26-8/30[G]	9/18[A]	9/23-9/27[G]	10/18[A]
25	563.4	8/23/2000	N.L.	N.L.	N.L.	N.L.	570.4	N.L.	462.4	N.L.	459.5
26	559.1	8/2	N.L.	575.7	N.L	574.4	574.4	573.0	N.L.	570.7 569.3	N.L.
27	562.0	8/22	N.L.	557.5	N.L.	N.L.	563.8	559.1	N.L.	560.9 559.1	N.L
1	578.7	7/10/2001	589.2	589.8	N.L.	N.L.	N.L.	N.L.	589.7	N.L.	N.L.
2	565.2	5/24	N.L.	N.L.	N.L.	559.1	N.L.	N.L.	N.L.	N.L.	N.L.
30	578.7	7/10	537.1	564.7	580.0	N.L.	577.0	577.3	545.1	N.L.	N.L.
22	578.7	7/10	580.6	579.6	N.L.	580.5	580.5	M	M	M	M
42[740]	569.9	8/23	N.L.	564.3 559.1	N.L.	558.8	N.L.	N.L.	N.L.	N.L.	N.L.
43[740]	569.9	8/23	N.L.	N.L.	N.L.	N.L.	N.L.	N.L.	421.4	N.L.	420.6
44[740]	559.1	10/18	N.L.	558.8	N.L.	559.1	N.L.	N.L.	N.L.	N.L.	N.L.
45[740]	559.1	8/31	N.L.	572.8	N.L.	569.6	569.9	N.L.	N.L.	N.L.	N.L.
13	572.8	6/26/2002	---	---	N.L.	N.L.	N.L.	N.L.	N.L.	N.L.	396.3
14	559.1	6/27	---	---	N.L.	N.L.	N.L.	N.L.	N.L.	N.L.	N.L.

Fish Code	Initial Capture Site (RK)	Initial Capture Date	2002								
			6/20[A]	6/25-6/28[G]	7/02-7/03[G]	7/23-7/26[G]	8/12-8/16[G]	8/26-8/30[G]	9/18[A]	9/23-9/27[G]	10/18[A]
12	579.2	7/24	---	---	---	N.L.	N.L.	571.8	570.4	N.L.	433.6
15	576.0	7/24	---	---	---	558.8	578.7	N.L.	N.L.	N.L.	486.7
41[760]	576.0	7/24	N.L.	N.L.	N.L.	N.L.	576.7	N.L.	486.7	574.4	N.L.
16	578.7	8/13	---	---	---	---	---	567.0	N.L.	N.L.	392.6
17	578.7	8/13	---	---	---	---	---	N.L.	548.0	N.L.	N.L.
42[760]	577.0	8/13	---	---	---	---	---	576.0	530.5	N.L.	456.1
45[760]	571.8	8/14	---	---	---	---	---	567.0	570.2	573.4	N.L.
43[760]	581.6	8/26	---	---	---	---	---	---	525.3	N.L.	428.0
44[760]	576.0	8/27	---	---	---	---	---	---	560.9	560.9	N.L.
117	581.2	9/23	---	---	---	---	---	---	---	580.0 567.0	N.L.
118	581.2	9/23	---	---	---	---	---	---	---	580.0	N.L.
110	560.9	9/26	---	---	---	---	---	---	---	---	467.4
113	560.7	9/26	---	---	---	---	---	---	---	---	N.L.
114	559.1	9/26	---	---	---	---	---	---	---	---	N.L.
# of Active Transmitters			12	12	14	16	16	20	22	24	27

Appendix 4. Aerial and ground survey locations of radio-tagged Colorado pikeminnow found in 2003. Transmitter code, contact date, and RK location for each radio-tagged fish implanted in 2001 and 2002. Abbreviations are as follows: A - aerial survey, G- ground survey, N.A.- transmitter is not active, N.L. - fish not located, M - Mortality, and Y - Yampa River.

					2003			
Fish Code	Initial Capture Site (RK)	Initial Capture Date	3/21[A]	6/30-7/03[G]	7/21-7/24[G]	8/11-8/13[G]	9/15-9/17[G]	10/22[A]
1	578.7	7/10/2001	N.L.	N.L.	N.L.	N.L.	N.L.	N.L.
2	565.2	5/24	464.3	N.L.	N.L.	N.L.	N.L.	449.1
30	578.7	7/10	506.8	N.L.	N.L.	N.L.	N.L.	N.L.
22	578.7	7/10	M	M	M	M	M	M
42[740]	569.9	8/23	450.5	N.L.	N.L.	N.L.	N.L.	483.3
43[740]	569.9	8/23	420.6	N.L.	N.L.	N.L.	N.L.	420.6
44[740]	559.1	10/18	N.L.	N.L.	N.L.	N.L.	N.L.	N.L.
45[740]	559.1	8/31	535.8	N.L.	N.L.	N.L.	N.L.	592.4
13	572.8	6/26/2002	N.L.	N.L.	N.L.	N.L.	N.L.	379.2
14	559.1	6/27	N.L.	N.L.	N.L.	N.L.	N.L.	N.L.
12	579.2	7/24	429.6	N.L.	563.3	572.6	568.0	433.6
15	576.0	7/24	521.3	560.7	559.1	575.2	529.4	462.3
41[760]	576.0	7/24	508.4	N.L.	566.5	578.6	N.L.	N.L.
16	578.7	8/13	398.7	N.L.	570.2	572.6	538.2	392.6
17	578.7	8/13	N.L.	569.3	564.9	580.4	547.4	535.3

			2003					
Fish Code	Initial Capture Site (RK)	Initial Capture Date	3/21[A]	6/30-7/03[G]	7/21-7/24[G]	8/11-8/13[G]	9/15-9/17[G]	10/22[A]
42[760]	577.0	8/13	N.L.	N.L.	569.3	N.L.	N.L.	594.5
45[760]	571.8	8/14	N.L.	N.L.	353.8	359.0	N.L.	512.8
43[760]	581.6	8/26	435.5	N.L.	566.5	571.7	526.9	429.9
44[760]	576.0	8/27	N.L.	N.L.	N.L.	N.L.	519.5	N.L.
117	581.2	9/23	550.3	N.L.	N.L.	N.L.	583.6 572.5	592.9
118	581.2	9/23	469.5	565.1	569.9	N.L.	N.L.	473.7
110	560.9	9/26	N.L.	N.L.	545.3	N.L.	N.L.	548.5[D]
113	560.7	9/26	476.3	N.L.	N.L.	563.1	557.2	N.L.
114	559.1	9/26	538.2	N.L.	N.L.	N.L.	545.3	N.L.
# of Active Fish			24	24	24	24	24	24